Atomic and Molecular Physics
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Lecture – 42
Rotation of a molecule

So, will continue our discussion on this rotation of a molecule so, rotation of a molecule, what it gives? It gives basically the microwave radiation.

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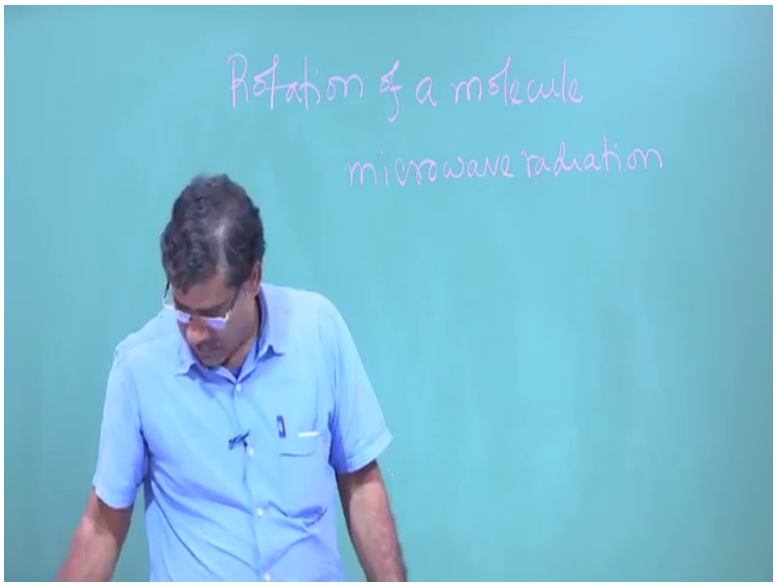

So, we want to see how it is giving this rotation of a molecule is giving microwave radiation microwave electromagnetic radiation ok. So, when we would like to study the rotation of a molecule.

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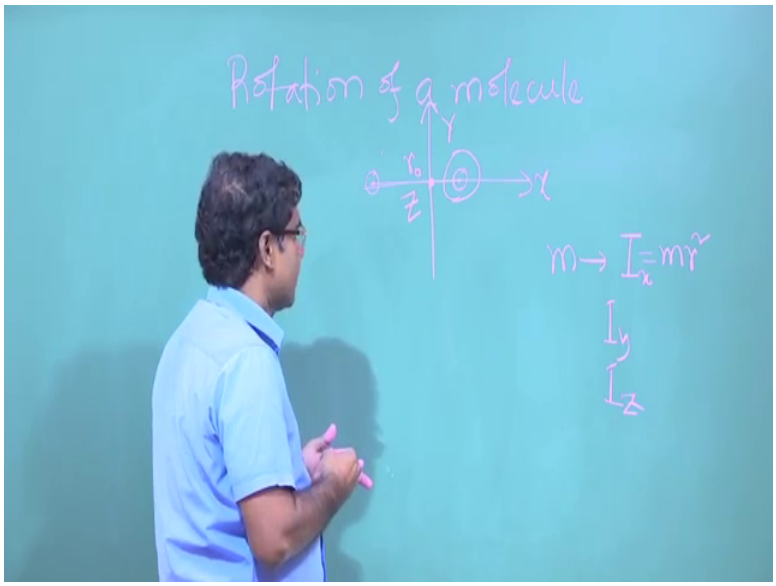

So, basically; so rotation of a molecule says you have a simple molecule between molecules, two atoms separated by a distance. So, two atoms separated by a distance. So, these distance is basically is called say bond length bonding between these two atoms, so it is called bond length. So, these to study, the rotation of a molecule so, rotation about an axis right rotation of anything that is basically about an axis ok.

So, we have to define axis to study the rotation of the molecule. So, mutually perpendicular directions through the center of mass so, here if this two molecules are identical, their mass are identical. So, center of gravity or center of mass it will be in middle, if one size is higher; like Hcl and another is smaller. So, its center of gravity, it will be, it will not be in middle, it will be close to the higher mass. So, we have to define, basically we define that three mutually perpendicular directions. So, that is the x direction say along these, the x direction along these it can be y direction and perpendicular to these board, so that is z direction.

So, rotation of these molecule it can be about the axis x axis, it can be about the y axis, it can be about z axis or it can be about any arbitrary axis. So, if it is about any arbitrary axis, so that can be, that one can get in terms of these three mutually perpendicular axis. So, for linear motion mass is important. So, in case of rotation equivalent is the moment of inertia right, mass is equivalent to moment of inertia. So, whatever the role mass plays in case of linear motion, so that is same, same rule are plays by this moment of inertia.

So, moment of inertia is defined as mr square right. So, from the axis of rotation what is the distance of this mass if it is r. So, this moment of inertia is I equal to mr square right, so this moment of inertia. So, if it is this, this axis is x axis. So, then you can write this is Ix if it is about the moment of inertia Ix, means this axis of rotation is x direction. So, similarly Iy, if it is with respect to y direction and then Iz so, Ix Iy Iz is; basically three moment of inertia with respect to three mutually perpendicular directions x y and z direction.

So, about which axis it is molecule is rotating. So, that is important, because of moment of inertia, because from that axis one has to take distance of the mass right, so direction is important. So, that is express; so that effect of direction or axis chosen. So, that comes through this moment of inertia. So, that is why if I write moment of inertia is Ix or Iy or Iz. So, indirectly it is telling what the axis of rotation is. So, depending up on this axis of rotation or moment of inertia we can define these basically depending on the molecule and that axis of rotation.

So, we can differentiate molecules and their rotation. So, let us see some example that linear; so different kinds of molecules are there. So, if we differentiate them in terms of their arrangement or in terms of their axis of rotation ok.

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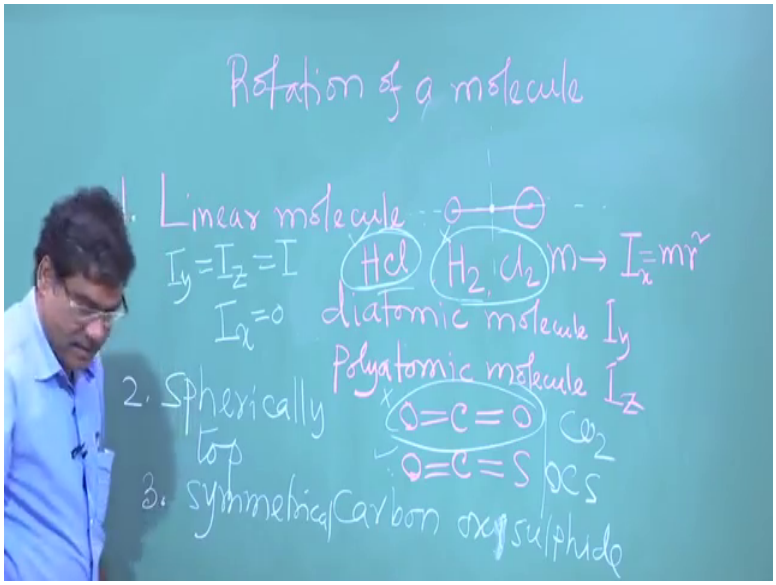

So, this one type will be called linear molecule, linear molecule. Linear molecule means atoms are arranged linearly in that molecule. So, like a Hcl, like a Hcl is linear molecule,

because each hydrogen and chlorine they are arranged linearly. So, Hcl is, this is the example of linear molecule Hcl H 2 also, H 2 also they, there are Cl 2 Cl 2 also they are they are linear molecule, and so this here what about example I have given. So, this called diatomic molecule

So, diatomic molecule is all the time linear molecule diatomic molecule, diatomic molecule is always linear molecule, but it is not necessary that diatomic molecule is only linear molecule, but polyatomic molecule also can be linear molecule. So, diatomic molecule so polyatomic example of polyatomic molecule so, these are the nomenclature or molecular spectroscopy. So, polyatomic molecule, it can be also these linear molecules say carbon dioxide, carbon dioxide Co 2. So, it is a more than two atoms. So, these their arrangements is like this arrangement is like this. So, this is linear molecule ok.

So, similarly I think carbon oxi suplhide, carbon oxi sulphide, carbon oxy sulphide oxy sulphide so, this also linear molecule. Now so linear molecule it can be diatomic molecule diatomic molecule all the time it is linear molecule, there is no choice, but polyatomic molecule also can be linear molecule, but I think most of the polyatomic molecule are not linear molecules, but there are many examples of linear molecules. So, here I have given two examples.

So, one is carbon dioxide, one is carbon dioxide another is carbon, I think this is written like this ocs carbon oxy carbon oxy sulphide. So, that is carbon oxi oxi sulphide oxy sulphide oxy or oxi, I can be oxi. So, carbon oxi sulphide so, it is the example of linear molecule and it is polyatomic molecule.

Now, here I have given these for diatomic molecule. So, Hcl and so H 2 Cl 2, these are the diatomic molecule and they are linear molecule, but this entire linear molecule, all these linear molecule it will have rotation. So, it will have rotation, there is nothing wrong to have the rotation of rotation of these, of these molecule, but as I mentioned earlier H 2 and this Hcl they are not microwave active, they are microwave inactive, because they do not have permanent dipole moment; that means, neither it will emit, neither it will emit microwave not they will absorb microwave ok.

So, but they will have this, they will have these rotation and they will not show any spectrum molecular, they will not show any molecular spectra in the microwave range.

So, due to rotation of this microwave non active molecule will not get any microwave spectra, but whereas, this Hcl will give microwave spectra.

So, these, this is microwave active molecules, this is microwave inactive molecule. Similarly for polyatomic molecule, this, these one carbon dioxide, it is not having the permanent dipole moment, it will not have the permanent dipole moment; whereas, this carbon oxy sulphide it will have permanent dipole moment.

So, in this case, these also will not, it is microwave inactive; whereas, this other one is microwave active. So, these are the example of linear molecule. So, that incase of linear molecule, in case of linear molecule. So, axis of rotation Ix Iy Iz you can just, you can just tell that in case of linear, linear molecule Iy equal to Iz. So, equal to I can write I, because both are and Ix equal to 0. So, Ix direction is taken in this direction.

So, Ix; obviously, it will be 0, because from this axis the distance of mass is 0 right. So, I equal to mr square distance r is 0 from this axis. So; obviously, your moment of inertia Ix is 0. So, for linear molecule; so only there is a one moment of inertia, only one moment of inertia, because of symmetry, either it is rotating with respect to y axis or with respect to z axis is basically same ok.

So, it is linear molecule have only one moment of inertia; however, is; so when the molecule will have only one moment of inertia, then; obviously, it is, it will be called the linear molecule. So, for other example we tell that, that is basically second case, I can tell this second case, I can tell that this, the other kind. So, this spherically, spherically top, spherically top molecules, spherically top.

So, it is in case of this linear molecule, it is in case of polyatomic. So, all the diatomic molecule under this group linear molecule, some polyatomic molecule also in this group, rest of the other polyatomic molecules, it can be, it can be, either it can be in these groups spherically top, spherically top molecules or third type.

It can be symmetrical top molecule, symmetrical top molecule, symmetrical top molecule, symmetrical top molecule, symmetrical top molecule and other case it can be asymmetric, asymmetric top molecule, other type can be four kind of four below I have space ok.

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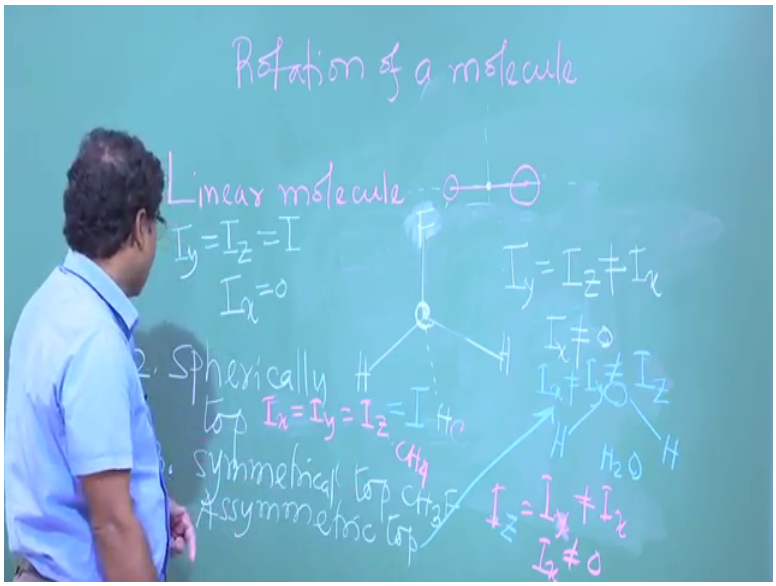

So, I can tell these asymmetric top molecule so, polyatomic molecule it can be linear molecule, it can be spherically top molecule or symmetrical top molecule or asymmetric top molecule. So, in case of spherical top molecule, example I can give you spherical top. So, basically this kind of tetrahedrally bonded, tetrahedrally bonded. So, spherically it will be spherically tough, when it is the carbon, it is the carbon and here hydrogen, here hydrogen, here hydrogen is basically methane node is methane.

So, methane they are, it is called spherically top, spherically top molecules. So, this basically in this case arrangement of this charge is basically, it has basically spherical symmetry, it has spherical symmetry and in this case, in this case you can define this x y z direction in such a way so, and you can show that you can see that y. So, this Iy equal to Iz fine, but Ix is not equal to 0, Ix is not equal to 0.

So, in case of spherically symmetric so, Iy equal to Iz, we can define this axis in such a x y z axis. So, you will have Iy equal to Iz, but Ix is not equal to 0. So, that is the difference between this, this linear molecule and this spherically top molecule and symmetric top molecule, what is symmetric top molecule? Symmetric top molecule is not spherical top, if you replace this one F by F if you. So, methyl fluoride basically earlier it was a methane. So, now, it is methyl fluoride, methyl fluoride. So, this three are hydrogen, this one is fluorine. So, then it will be called symmetric top molecule, it will

be called symmetric top molecule, and in this case your; yes symmetric top. So, I think this the mistake I have done.

So, in this case I have done mistake. So, for spherical top molecule you can define this one Ix equal to Iy equal to Iz Ix equal to Iy equal to Iz when this spherically symmetric. So, this, the case, but in case of this symmetric top, when it is methyl fluoride, methyl fluoride, so in that case, so Iy equal to Iz, but Ix is not equal to Ix and Ix is not equal to 0 ok.

So, yes. So, spherically top here basically ix equal to, I think I will use the different color. So, Ix equal to Iy equal to Iz and symmetric top molecule, symmetric top molecule this is the example. So, here spherical top molecule example is C methane Ch four methane and symmetrical top molecule, this is the methane flouride Ch 3 F Ch 3 F methyl flouride. So, this is symmetrical top molecule, and in this case, in this case basically your Iy equal to Iz Iy equal to Iz, but not equal to Ix, and Ix is not equal to 0, Ix is not equal to 0, Ix is not equal to 0.

So, this is the, here whatever I have written, so that is basically for symmetrical top molecule and then asymmetric, asymmetric molecule, asymmetric top molecule. So, asymmetric top molecule example is for asymmetric top molecule, example say example I can tell this water O and then you have hydrogen here, hydrogen.

So, this water m molecule is basically H 2 O, it is H 2 O water molecule have asymmetric is called asymmetric top molecule, because in this case. Basically in this case Ix, Ix is not equal to Iy is not equal to Iz is not equal to Iz. So, in terms of moment of inertia the molecules or divided into different types.

So, those molecules are called linear molecule, where it will have only one moment of inertia only one moment of inertia principle, principle moment of inertia, it is called principle axis with respect to principle axis, principle moment of inertia. So, that is the linear molecule, it can be diatomic molecule, it can be polyatomic molecule. So, that example I have given. So, second is spherically top molecule.

So, when all three moment of inertia exist, but they are equal Ix equal to Iy equal to Iz so, it will have also basically one moment of inertia equal to I equal to i, but in this case Ix is not equal to 0. So, that why spherically symmetric molecule is different from the

linear molecule. So, in case of spherical top molecule, that entire molecule will be called spherically top molecule, when their principle moment of inertia are equal.

Yes, then symmetrical top molecule, it will be those molecules which will have these, these moment of inertia. I think here I should write yeah, say Iz equal to Iy is not equal to Ix. So, and Ix is not equal to 0.

So, it is different from these spherical top molecule or linear molecule. So, in this case Iy equal to Iz, but Ix is 0. So, linear molecule, when Iy equal to Iz is not equal to Ix, and Ix is not equal to 0. So, then this is spherical, this is symmetrical top molecule, and when Ix Iy Iz they are not equal with each other, and they are not 0 also.

So, Ix is not equal to Iy is not equal to Iz. So, if this is the case, so those molecules are called asymmetric molecules. So, depending on the axis of rotation and their corresponding principle moment of inertia so, this in molecular spectroscopy, molecules are differentiated by this way. So, I will stop here then I will continue in next class.

Thank you.