Atomic and Molecular Physics
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Lecture - 56
Atomic and Molecular Spectroscopy

So, so, far we have we have studied the rotation of a molecule, pure rotation of a molecule and then pure vibration of the molecule, and then electronic structure of a molecule. Now in electronic structure basically vibration as well as rotation are involved there comes together right. So, this is the overall the basic fundamental study of the molecular physics.

So, now as you know these atomic and molecular physics is basically based on the spectroscopy. So, these to study the structure atomic structure and molecular structure so, one has to use spectrometer spectroscopy ok. So, that is that is why there are various kind of atomic spectroscopy and molecular spectroscopy ok; so, in different name ok.

So, today I will discuss about one spectroscopy that is basically called it is its very useful for first for studying the rotation and vibration of the molecules. So, that spectroscopy is basically called this Raman Spectroscopy Raman spectroscopy ok.

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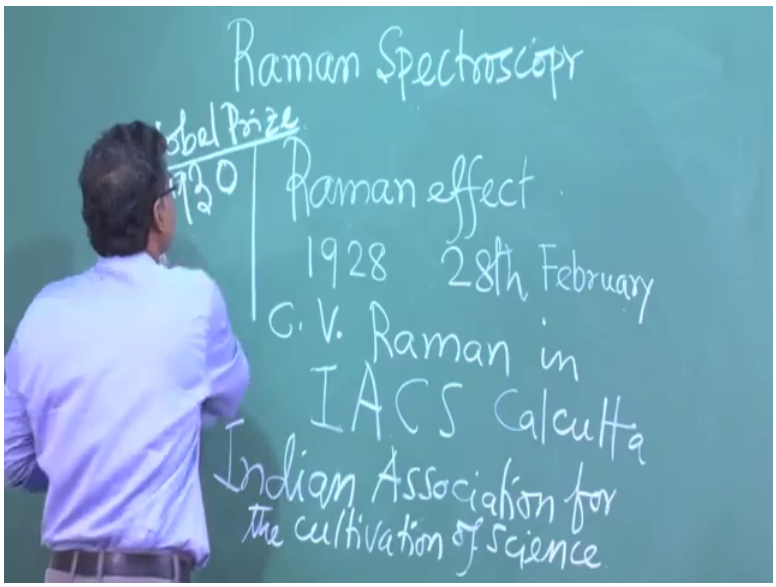

So, these spectroscopy based on the Raman effect.

So, you know the history of the discovery of the Raman Effect Raman Effect ok. So, what is that what is Raman Effect? So, it was discovered in 1928 1928, I think that is on that that day the 28th February was probably yes 28th February it was discovered 1928, it is the 28 February it was discovered by Raman C V Raman it was discovered by C V Raman in an research institute in a research institute that is called this IACS Kolkata in IACS Kolkata that time it was Calcutta IACS Calcutta ok.

So, IACS that this is basically Indian association for the cultivation of science Indian association for the cultivation of science I do not know whether you have seen this institute in Kolkata it is in jodhpur, but earlier when C V Raman works for this for the for his research. So, that institute was in Bavaria it is in Kolkata. Now, it is shifted to jodhpur, but this them is same IACS Indian association for the cultivation of science Indian association for the cultivation for the cultivation for the cultivation of science ok. It is just the opposite side of Jodhpur University.

So, this C V Raman, he was basically he was general accountant in his posting was in Kolkata because after MSC, I think he C V Raman he did his BSC from Presidency College Madras, when he was 16 years old he completed his BSC, he stood first in the class and he was the gold medalist ok. And I think when he was 16 years old BSC and in I think when he was 18 years old he completed the MSC from Pesidency College Madras and then for further study one has to that time one has to go to London, but he was somehow his health was not good. So, that is why he did not he was not able to go to London for further study.

So, then he choose the job this is the; I think this very prestigious job financial department of British and this is called accountant general and his posting was in Kolkata. So, so he used to he used to go to office by trump and when. So, when he was going and coming back so, one day he saw a research institute his name is his Indian association for the cultivation of science in Bavaria, and then he got down from the tram and he went there and he found his suitable place to do some research and he started research no raptor of Ishyama.

And he I think yeah I think he did lot of research work, but this the ultimate his this is the major success of his research this discovery of Raman effect and in 1928 and immediately he got the Nobel prize after just after two years of this discovery.

So, 1930 he got the Nobel prize. So, this is the first Nobel prize got by Indian I no I think Rabindranath Tagore before that Rabindranath Tagore, but in science he was about the probably fast this is the first Nobel prize in physics one Hindi and got this C V Raman, but before that year in literature I think Rabindranath Tagore got.

So, Nobel Prize in 1930 Nobel Prize ok. So, that was the brief history of the discovery of the Raman effect, but what is that effect, what is the what is that Raman effect. So, actually in general is the scattering of light is the Raman Effect basically is the scattering of light from.

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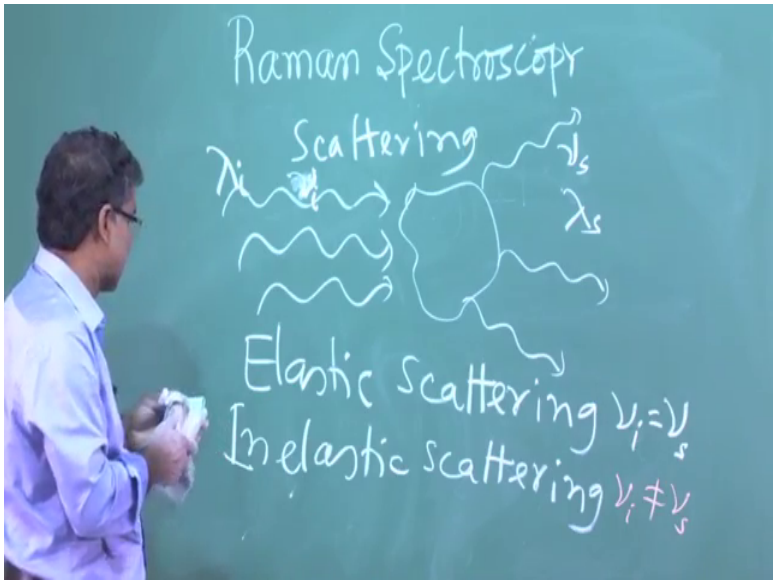

So, if light or electromagnetic radiation it may be visible light or this other electromagnetic radiation, when it falls it falls on a sample ok. Now, this light scattered from this matter from this substance from this object right ok. So, now, there are two types of scattering. So, this is again scattering. So, there are two types of scattering one is called elastic scattering another is called inelastic scattering elastic scattering and another is called inelastic scattering ok.

So, what is elastic scattering? So, this light or incident radiation falls on the object and it is this incident light or radiation scattered by this object and this scatter light in all directions, if the wavelength or frequency say incident radiation, it is frequency say or nu i or wavelength lambda i or wave number whatever ok. If this and then scattered one this if I write nu s of lambda s ok. So, if nu i if nu i equal to nu s incident one and then

scattered wave length of the scattered light if it is same, then it is called elastic scattering. If it is not if it is not same if it is not same, nu i is not equal to nu s then it is called inelastic scattering ok.

So, Raman scattering was basically it is the it is inelastic scattering Raman scattering as inelastic scattering. So, Raman scattering was inelastic scattering.

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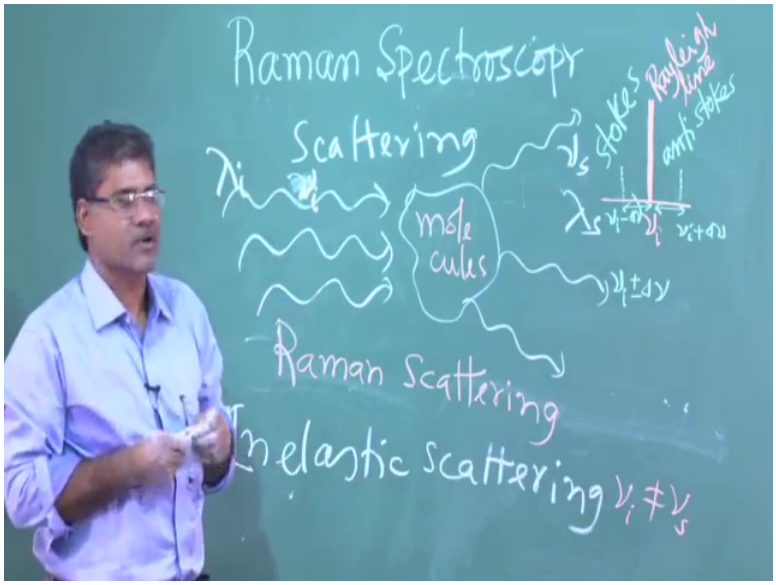

Raman scattering is basically inelastic scattering. So, what Raman found that when the sunlight when light sunlight or yeah or light from I think from mercury source ok, when we put on the on the sample of molecules of the sample of molecules ok. So, then this incident light is scattered by these molecules by this sample, sample is of molecules scattered by these molecules ok.

So, then he found that he found that most of the light have most of the light have the frequency of incident wavelength or incident frequency ok, but there are some scattered light very weak light means scattering strength is very small. So, he got basically in spectrometer in spectrometer, when he when he checked the wavelength of the scattered light.

So, he found he found basically he found basically, this one strong lines one strong lines having the frequency of incident light or radiation and then this two additional lines he saw, but it is a very weak lines. So, one is higher than the original frequency are

wavelength, another one de lower frequency are wavelength and their separation these are separation is basically same the separation is basically same and that is what I think yes.

So, this frequency the frequency difference that difference was basically say if it I write del nu ok. So, he found the two other lines of frequencies basically nu i plus minus delta nu plus minus delta nu. So, frequency of this one frequency of this one is say. So, frequency of this one nu i minus delta nu and frequency of the other one here nu i plus delta nu plus delta nu ok.

But intensity of these two lines are very weak and this two lines he called this line. So, on stokes and anti-stokes lines stokes and anti-stokes line. So, this line at lower frequencies called stokes lines s t o k e s stokes lines, stokes line and this called anti stokes lines stokes line and anti-stokes line and this original one this the it is its it is called Rayleigh scattering, this because it is called Rayleigh scattering or yeah Rayleigh scattering so, one can tell this Rayleigh line. So, original the same frequency and highly intense other two is very weak, and this frequency of these two is plus minus del nu original plus minus del nu. So, this lower frequency one, this line is called stokes lines and other line another is anti-stokes.

So, now Raman basically, earlier it was not known these two lines stokes line and anto stokes line. It was so, weak and it was very difficult to see that one and problem was earlier this all experiment was done using the sunlight that was the most intense light later on this some mercury light arc light etcetera this was came off and Raman was able to see these two lines if it is scattering is very weak.

So, if you can increase the intensity of the intense light, then there will be higher probability to have to get this higher probability to get this scattering what I mean this. So, then this you will get. So, scattering instant it is defined it defined basically per unit per unit per one say here is kept scattering center and part one this what I equal per one way you can see tell of it is particle par one particle incident particle that is the scattering instant.

Now, strength we will not increase, but you see this if you can increase this one, this total cross section scattering cross section you see it will be. So, whatever the intensity will get there so, that is that depends the scattering cross section scattering strength, and also

intensity will depend on the number of these number of these incident photons as well as the number of the molecules say here in this case the number of the scattering center ok.

So, so if you if you increase if you increase either the number of scattering center or the number of incident particle or incident photons. So, it is possible to get the comparatively higher intensity, which can be detectable ok. So, that is why Raman was able to see this one because he used this lens to focus to focus the to focus the light and put the focused line on the on the sample ok.

So, that what is the I think because of that he used these higher bigger diameter lens and he was able to he was able to condense or converse the light or light on the sample. So, does incident intensity of light was high and because of that he was able to see this very weak lines ok. If this intensity is not high enough, it is it is so, faint it is people will overlook that one anyway.

So, so that is was the; so, that is that is not observed by the by the Raman and this is called Raman effect and he explained what is the our from higher this extra to line as come from where these two extra lines are coming stokes lines and anti-stokes lines from higher it is coming. So, that is what he experimental observe and he explained the origin of these two lines and he explained that this is this is coming from the from the molecule and it is due to the rotation and vibration of the molecules these strokes and anti-stokes lines or terms. So, origin of the stokes and anti-stokes lines is basically is basically due to the vibration and rotation of the molecules ok.

So, Raman spectroscopy is does it is related with the with the molecular spectroscopy. So, these spec spectroscopy is now it is it is a very useful research to instrument to study the different kind of molecules, to study the vibrational and rotational structure of the molecules and some other for in case of solid etcetera now these it has vast application. But discover wise it was just it was observed due to the due to the molecular vibration and rotation and now this application of it is expanded in different direction, main reason is that this now laser light is available laser light have it is focused and it has tremendous intensity and it is monochromatic wavelength means it has single wavelength.

So, now Raman spectroscopy is very simple one and it is used it is used yeah this it is used means this Raman spectroscopy is I think it is all over the world it is a people have

this spectroscopy or spectrometer. So, let us see now that how Raman explained this origin of the of the strokes and anti-stokes lines now you see so.

So, now, we have one has to differentiate is this, it is related with the rotation and the vibration that is fine and also we have seen this just pure rotation and pure vibration of the molecules what happens that we have seen when than the they are also involved they come together with the electronic transition ok.

So, this basically here one that I will tell you in this case the difference is that this remember when I was telling this absorption spectroscopy. So, so they are absorption spectroscopy. So, they are what we have seen this. So, this pure this vibrational spectra and that is the that we have we have seen these molecules, it absorbs the some wavelength and that wavelength is because of the is related with the vibration of the molecules right.

So, emission spectroscopy that is other way, if you excite the if we excite the molecules and then it will emit light ok. Now if you study that that light emitted from these molecules. So, now, that is that is the emission spectra ok. So, here in this case incident light. So, humidity the incident light focus light or nowadays laser light is used, laser light will fall on your sample not sample now sample is basically say simplest molecule. Now this now the molecule now the incident light will be scattered from this from this sample from these molecules and this it is geometry is that now the scattered light the studied in spectrometer this scattered light at 90 degree. So, this is the incident direction of light.

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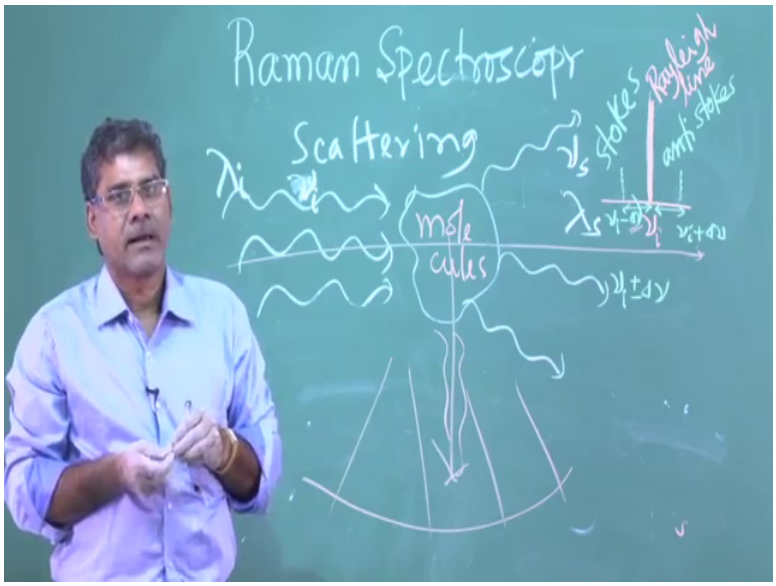

Now, at 90 degrees the spectrometer is set up set and this scattered light is collected at 90 degree and put in spectrometer. Now spectrometer is standard you know this one has to use getting that kilometer will be there, telescope will be there and this premium table will be there. So, premium table spectrometer table; so, on table this in this case generally now generally now grating is used; now you understand that why grating is used because what are the wavelengths are coming that I want to see that I want to measure right. What are the wavelengths are coming that I want to measure. So, so to separate that wavelength, one has to use either not this grating.

So, to separate to keep spatial separation to make spatial separation of the wavelength ok. So, to basically dispersion grating and prism both are have dispersive power. So, to disperse the wavelength is space. So, that is why there is a now you will measure the you will one has to use the detector photomultiplier tube if it is visible light and then, then you will you will measure the intensity of light of the scattered light it is coming through the prism of the or the grating. So, what are the. So, you will measure the intensity at different places means, different places you will have different wavelength right.

So, that wavelength how it is specially dispersed so, that that is related with the with the vision parameter or the grating element grating parameter. So, thus you will measure the does you measure the intensity of intensity of intensity of different wavelength of the scattered. So, then when we will measure, then this found that this original at this

wavelength things are coming, most of the scattered light are at this wavelength and there are other two wavelength also it is observe or frequency also is absorb.

So, what are the intensity. So, that is the Raman suggest sketch of the Raman spectrometer it is used. So,. So, you will get this kind of this spectral spectrum, which will have this three wavelength three wavelength and you may have the more wavelength, but that that depends on that will depends on the because the del nu as I told this del nu how much it is, how much it is it will have the value so, that depends on the depending on the molecule ok.

So, del nu will be different for depend molecule and some powerful for other condition bonding etcetera, when molecules are in solid form or liquid form whatever. So, these are the. So, so del nu will be different and del nu who is related with the molecules, molecular vibration rotation ok. So, measuring this separation measuring this separation now one can one can relate with the structure of the molecules.

So, thus this is the research matter and this and not only this one two lines you can have many lines, that because of many factors many factors in this in this sample it is may not be it is single same type of molecule, there may be existence of other type of molecules or some other factors, but for simplicity this one kind of molecule simple molecule dipole molecule, in this case this you will get only these two lines an additional in addition with this original frequency ok.

So, these the geometry Raman spectroscopy that is the spectrometer the geometry, and these the lines are observed and this I will show you this is related with the with the rotation and vibration of the molecules. So, I think this I will discuss in next class. So, I will stop here.

Thank you.