**Experimental Physics - III**
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**Lecture – 44**
**Study of Absorption Spectrum of Iodine Vapour**

See you are welcome to our modern optics lab of Department of Physics IIT Kharagpur. Today I will demonstrate Absorption Spectra of Iodine molecules.

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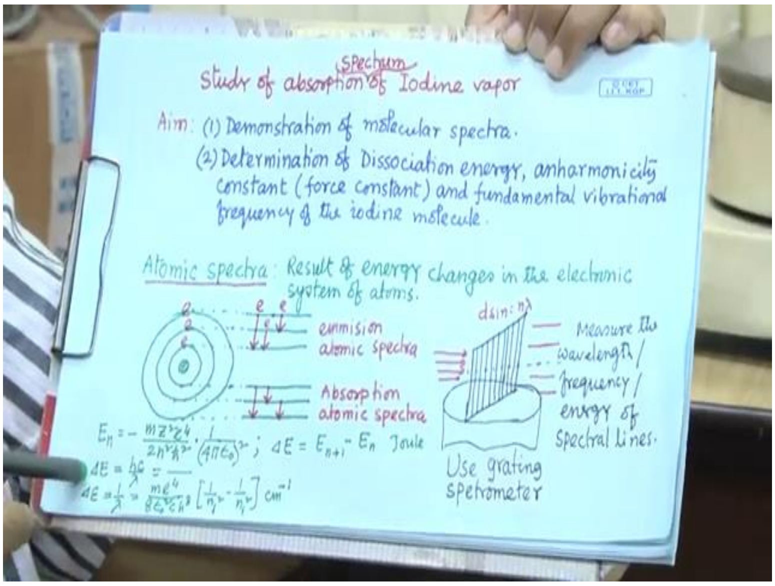


What is the aim of this experiment? Aim of this experiment is demonstration of molecular spectra, you are quite familiar with the atomic spectra and in Experimental Physics II, and we have demonstrated few experiments on atomic spectra.

This is new kind of spectroscopy molecular spectroscopy. , that we will demonstrate. Second: determination of dislocation and determination of dislocation or dissociation energy anharmonicity constant from there one can find out force constant and fundamental vibrational frequency of the iodine molecule.

We will show the molecular spectra of iodine vapor and we will take data, from that data after analyzing we can find out the dissociation energy of the iodine molecule. Dissociation energy means it is a molecule when you will excite it with temperature.

Then molecules can dissociate into atom. , that is molecule to atoms that dissociation how much energy is required. , that is the dissociation energy and anharmonicity constant is the spectra whatever molecular spectra we will see that is vibrational spectra.

Two atoms in the molecule will vibrate and their potential energy will change, it is not simple harmonic motion, it is not like simple symmetric vibration of the two molecules; two molecules with respect to the equilibrium position or centre of the equilibrium distance. , it will be it will be asymmetric this vibration will be asymmetric. , that is why it is an anharmonic oscillator; it will behave like an anharmonic oscillator. , what is that anharmonic constant; that is called anharmonicity constant.

That also we can calculate as well as fundamental vibrational frequency that al one can calculate. , atomics spectra you are quite familiar with that and what is the origin of the atomic spectra? , atoms it has energy levels higher electrons stay. Now, if we excite the atoms then it jumps to the higher energy levels and from higher energy levels after few millisecond or microsecond it just come back to the lower energy state and energy difference between the energy levels that come out as a light as electromagnetic waves.

That we see that wavelength of that light we measure from there you can get the information about the energy levels of the atoms. , you we know we can find out the atomic structure from this measurement, from this analyses of the atomic spectra. , it can be two types of spectra emission spectra; emission in an atomic spectra and absorption atomic spectra.

Emission atomic spectra means as I told that from lower energy level to the higher energy level electron will jumps after me excitation and then it will come back, it will emit the light. In addition, another type absorption atomic spectra they are they are atoms are; atoms are in downstate, electrons are at lower energy levels now if it absorbs me photons, then it will jump to the higher energy levels.

If you expose these atoms with the radiation having continuous wavelength, then this atoms will absorb me of the photons me of the light having particular wavelength, particular energy. ,. , that light is in is absorbed by the atoms and then the rest of the light whatever will come out from the after absorption of the by the atoms.

If you analyze that one then you will see the black lines me lines are missing; me lights are missing, that you will see in the as a as a black lines. , that we tell that they are absorption spectrum. this from simple theory of about the atomic structure.

From there this energy levels the energy of this n th energy levels is these and then if you take difference between the two energy levels, corresponding energy del E., that del E hc by lambda. , energy difference will give you the light electromagnetic radiation.

Wavelength if it is lambda then this is the hc by lambda. , that is the relation with the energy difference between the two energy levels. , that al we express in terms of; in terms of. , this energy generally we can express as a Joule or the electron volt, but in spectroscopy generally we prefer to express this energy or yeah. , energy levels or the wavelength of light, that is the inverse of wavelength; 1 by lambda, in centimeter inverse.

To convert this daily energy. , if you just divide by hc if you divide by hc. , here I have written del epsilon, it is a different notation. , equivalent to energy, but it is the in centimeter inverse. , that will be this kind of relation it is a quite familiar relation to you from Bohr model.

This n f and this n I; , for different value of n f and n i you will get different transition lines, you will get different spectral lines and this corresponding spectral lines what is the wavelength that you can calculate from here. As well as experimentally using grating spectrometer generally, we use grating spectrometer. , this light will fall on the grating and the other side we will see the atomic spectra.

This will get different order of diffraction. , n is 1, 2, 3, with respect to the central position. , left side and side we will get first order, second order other side al first order, second order. , then using the using the circular scale of the spectrometer we measure the deviation angle and that is theta.

Here theta is missing it is should be sin theta equal to n lambda.  In addition, d grating element that is given. , One can find out the lambda or one by lambda from here. This is the way we analyze the atomic spectra.

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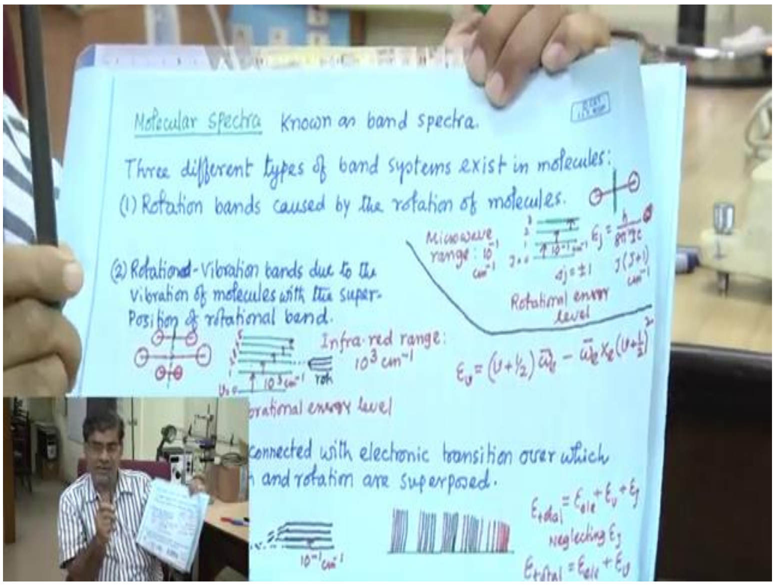


Now, as I told this is the different kind of spectra we will use today, we will demonstrate today. , that is molecular spectra, it is al known as band spectra. , in atomic spectra we have seen the isolated lights, but in case of molecular spectra, we will not see only line we will see a branch of line together, that is called band.

Molecular spectra is band spectra. , that I will show you in our laboratory. , this origin of these band molecular spectra is it is a., that it is a different type here I have noted down. , Three different types of band system exist in molecules. , one is rotational bands caused by the rotation of molecule; see in case of atom there is the question of rotation, but when it is molecule diatomic molecule say.

Then these two atoms or there is say they are bound with the bonding. , there is a bond length. , it is a dumbbell kind of things. , it has option to rotate; it has option to rotate. , and it does this molecule in the system this molecule are not static it rotates with respect to say this axis or this axis about an axis al it rotates.

When it rotates, its rotational energy al quantized. , it can rotate with different energy and that energy are quantized; that energy are quantized and the rotational energy here I have written epsilon J; J is the rotational quantum number. , this is h by 8 pi square I C where, I is the moment of inertia; I is the moment of inertia of this system and C is the light velocity.

The energy it is in centimeter inverse this into J plus 1. , here we have neglected the distortion; distortion part. , I think I forget that one there are other terms. , that we tell that it comes from distortion that I have not included here. , the rotational energy it is quantized it depends on J quantum number you know. , this is energy levels rotational energy levels will be like this. , this here there will be transition following the selection rule del j equal to plus minus 1 and you will get spectral lines; you will get spectral lines.

These are rotational spectral lines, but the energy difference between these two energy levels is in the order of 10 to the power minus 1 centimeter inverse. In case of electronic transition, in case of atomic transition they are the transition because we will tell electronic transition, transition of electrons from one energy level to the other energy level. , there these energy difference between the two energy levels is in the order of 10 to the power of 5 centimeter inverse, whereas here it is 10 to the power of minus 1 centimeter inverse, see it is a very small this energy level and that change is very small .

The spectral lines rotational spectral lines will get their wavelength will get in the in microwave range this will give microwave range that is why this rotational spectra spectroscopy we tell microwave spectroscopy. you need special arrangement for measuring such type of very small energy difference. , that is different spectroscopy, but in our case it is it we will use slightly different technique. , that we will discuss.

If it is molecule if not atom. , then electronic transition that will be there because in molecule electrons are there, but apart from that additional; additional degrees of freedom will be there. , this one is rotational rotation. , for that there will be in the in the molecule there will be quantized energy levels and in that quantized energy levels there will be transition for that we will get rotational one can get rotational spectra .

Second one is rotational vibrational bands due to the vibration of the molecule with the super position of rotational band. , another kind of spectra you can see in from molecule. That is called rotational vibrational band. , it is the mainly this spectra a band you will see because of the because of the vibration of the molecules vibration of the atoms in the molecule. , Two atoms, it will vibrate it will vibrate.

Compressed and elongated compressed and elongated. , due to vibration there will be set of energy levels again these energy levels are quantized and it is expressed by the by the vibrational quantum number here I have written v and their energy in centimeter inverse, the energy is v plus half this omega e bar or one can write omega e al there is no problem. , that is a frequency minus omega e bar X e v plus half square. , these terms, these you can think. , this is the vibration this is the harmonic oscillator for harmonic oscillator what is the; what is the energy level you know this is n plus half into this frequency nu here nu bar.

That I have written omega bar. , this is harmonic part and this another part here higher order term v plus half square. , that is anharmonic term. , i t is a behave as an it will behave like an anharmonic oscillator. , the energy is energy of the anharmonic oscillator is like this. , this is harmonic oscillator model. , with this with this energy, this molecule will have the energy what about the expression we have written here for different v when v equal to 0, then that will be downstate energy level and then v equal to 1, 2, 3, that will be for excited energy levels.

Now, it is an it is a vibrating as well as it can rotate al it can rotate also. This rotational; this rotational energy levels al superimposed with this with this vibrational energy levels. That is why it is a most of the time we see not only vibrational spectra, but under me conditions special condition one can see the only vibrational spectra, but in general one will see the vibrational spectra along with the rotational spectra .

Now, here you can see you can notice that in vibrational energy levels. , this difference between the two energy levels is typically 10 to the power 3 centimeter inverse, here it is 10 to the power minus 1, here 10 to the power three centimeter although this is again smaller than the electronic transition.

In electronic transition as I told that it is the 10 to the power 5 centimeter inverse is the in that order. , here separation between the energy level vibration energy levels are higher than is very high than the than the rotational one. , here is.

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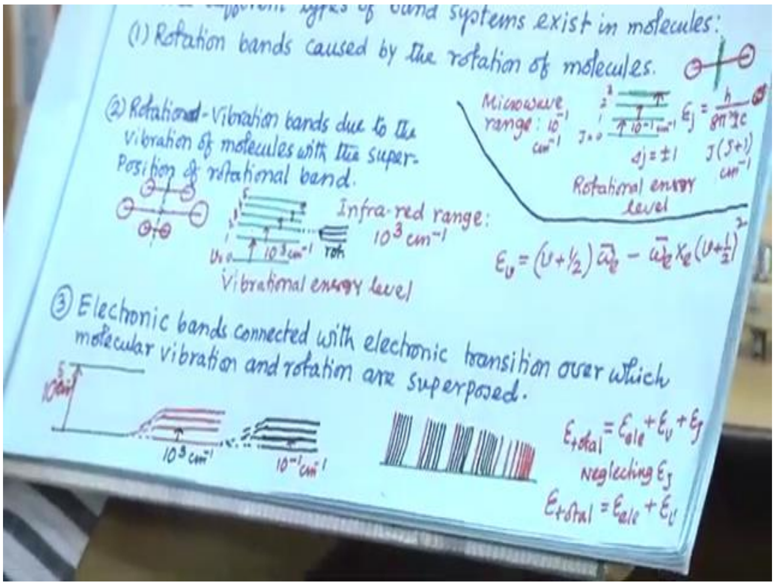


Third, one I have mentioned third type spectra I have mentioned here electronic bands connected with electronic transition over which molecular vibration and rotation are super imposed. , in molecule as I told electrons are there.

There will be electronic transition for that you will get; you will get; you will get the electronic spectra. That is not that is different from the atomic spectra because in molecule this energy level electronic energy level will be modified. For that for electronic transition you will get spectra and when there will be electronic transition electrons will go from one energy level to the another energy level. , along with that vibration of the atoms that will be there rotation of the atoms rotation of the molecules that will be there.

All three together you may see you may get, then that is it will be this type of spectra. This say this is the electronic energy level. This energy separation is ten to the power 5 centimeter inverse and now each electronic energy levels are associated it has associated with the vibrational energy level.

Here I have shown these vibrational energy levels, that separation is 10 to the power 3 centimeter inverse, and then each vibrational energy level is associated with the rotational energy levels. , their separation is 10 to the power minus 1 centimeter inverse. , Here whatever the I have drawn, in excited electronic energy level. , this vibrational as well as; vibrational as well as these rotational energy levels will be there. , when transition from these from these lower electronic energy level to the higher electronic energy level. , from lower energy levels, it has again vibrational levels.

It can be one of this vibrational level. In addition, it can go to the higher energy level higher this electronic energy level. , there al vibrational levels they are. , it can be at different vibrational level, that whatever the spectra we will get. , in that spectra we will it will have; it will have the information of the vibrational level. Again, each vibrational level has this rotational energy level. , from here, from this vibrational level means it can be from one of the rotational energy level. , and it will jump to the higher energy level.

They are higher vibrational level and then again in that vibrational level one of the higher rotational energy level. , whatever spectra we will get that spectra for a for a particular electronic transition; for a particular electronic transition there will be many; there will be many transition from the vibrational energy level. In addition, for again for each vibrational level there will be many; there will be many rotational transitions among the rotational energy levels. , that is for a particular electronic transition. , for a particular electronic transition here what we will see the spectra for whatever spectra we will see, that is you can see here.

Red line I have I have drawn here, that is say vibrational level. , because this is fixed the transition; the transition between two electronic states that is fixed now in that two electronic states different transitions from vibrational and rotational energy levels . , if this red one; if this red one is vibrational one this red if I see red this type of vibrational energy levels we will see and when this if you go this side you can see the separation between the vibration energy level are decreasing that are decreasing that is due to anharmonicity; that is due to anharmonicity from here you can see that for higher v; for higher v.

The energy the energy will decrease; energy will decrease. , energy separation will decrease, that you will see. , if you just lo at the vibrational spectra, these are red lines; red lines. , the separation between the vibrational spectra or that that separation between the successive two vibrational energy level, that we will decrease.

That we should see in the molecular spectra and now each vibration level. , there will be very closely spaced there will be black line I have shown for each vibrational level; with each vibrational level there will be a set of spectral lines. , that is because of rotational.

, the energy these energy is very close to the vibrational energy because this as I told this separation is 10 to the power minus 1. , this kind of band you will see in the molecular spectra. , we will use iodine molecule and we will show the iodine molecular spectra and there you will we can expect these type of spectra. Now, instead of atomic spectra; instead of atomic spectra we will see these molecular spectra. , we have used the; we have used the grating spectrometer for atomic to study the atomic spectra.

, in this case al we will use the; we will use the grating spectrometer and these will get in the visible range; these will get in the visible range. , now, you may be surprised I am telling this is the; I am telling this is the vibrational spectra and it should be vibrational spectra in generally it is in infinite region. , how we will see it in visible range? , that is what I should explain.

, this is ; this is  we are getting these spectral lines; these spectral lines having the information this electronic spectra that energy difference plus the; plus the this vibrational energy level ; plus this vibrational energy level.

, this one is not the spectral lines whatever the wavelength we will get or energy we will get of the spectral lines it is not in the range of infrared, it is in the range of visible range because it is a it this spectra is having the energy of; the energy of the vibration one plus the electronic one plus the plus the rotational one.

, from this spectra we will find out the information of the vibrational one although we will neglect the; although we will neglect the rotational one only we will consider on the vibrational one. , how to do that that is what I will discuss.