Atomic and Molecular Physics
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Lecture – 41
Physics of molecules

So, will start molecular spectroscopy or physics of molecules.

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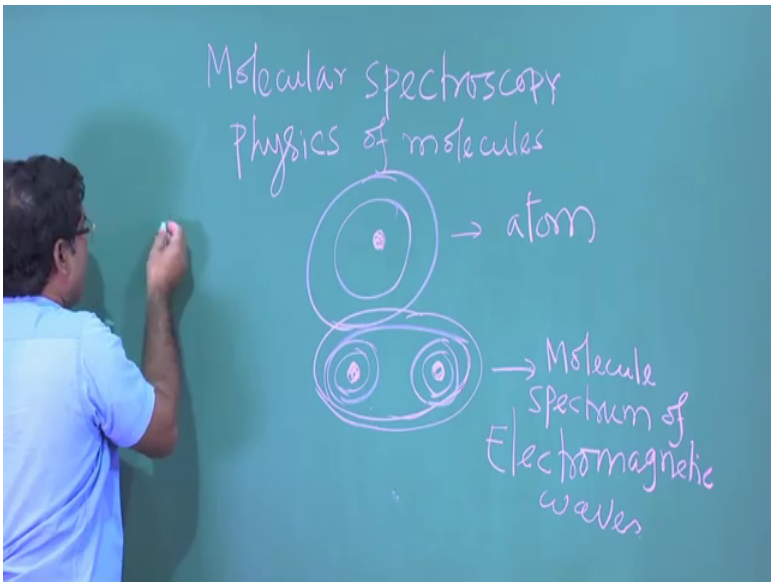

So, we have we have studied the physics of atoms or atomic spectroscopy. And now we will see about the molecules. So, what is molecule basically? Atom is defined by bound system of electrons and one nucleus right. So, basically one nucleus and there are many electrons one or more electrons. So, they are bound together so then it is a atom.

Now, molecule is basically a bound system of electrons with more than one nucleus. So, when one nucleus electrons bound with one nucleus then it is atom, when electrons bound with more than one electron nucleus then it is molecule; so, or for diatomic molecule. So, it has basically 2 nucleus and then electrons electrons bound together with these 2-nucleus ok. So, then it is a molecule molecule. So, a structure is basically structure of atoms or structure of molecules is basically how these electrons systems of electrons are bound with the nucleus if one nucleus.

So, then that is atom so that is basically atomic structure and for more than one electron nucleus ok. So, then it is a structure of molecules. So, we want to study the structure of molecules means, how system of electrons are bound are arranged with more than one elect nucleus right.

So, to study the structure of atoms or molecules basically ah, we take help of electromagnetic radiation when. So, these atoms or molecules or matter when interact with electromagnetic radiation then basically we get the spectra of atoms or spectra of molecules. So, studying the spectra of atoms or molecules after analyzing, we get the information of their structure. So, so basically the interaction of electromagnetic waves with matter when matter is in form of atom or is in form of molecule ok, will tell us about the structure of atoms or molecules.

So, so one should have knowledge of these atomic interaction with atom and molecules of electromagnetic radiation. So, next let us see the division of electromagnetic radiation, in terms of wavelength, in terms of frequency or in terms of energy. So, we would like to see the spectrum of electromagnetic radiation basically electromagnetic radiation or waves ok; so, spectra spectrum of electromagnetic waves. So, spectrum means this special distribution, special distribution in terms of wavelength or energy or frequency. So, that is basically called the spectra or spectrum. So, in case of electromagnetic waves what is the special distribution of electromagnetic waves that I think I will show you.

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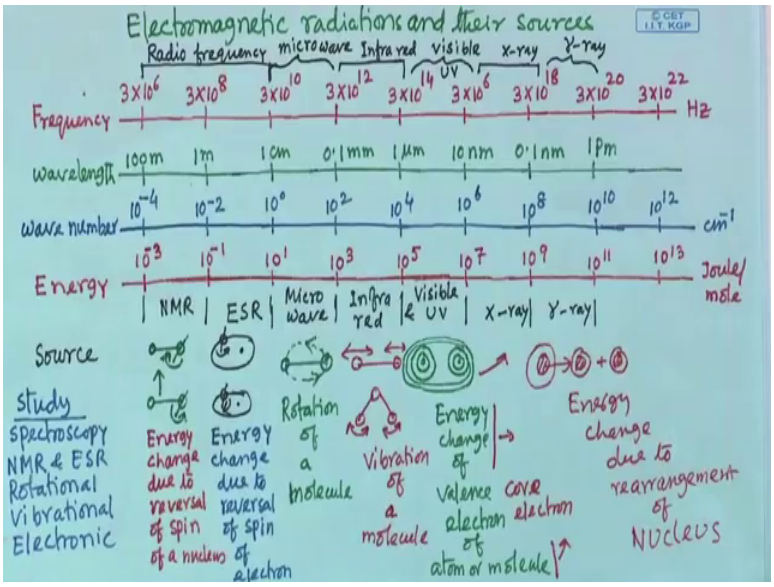

So, here you can see that electromagnetic radiation and their source means what are the sources of this electromagnetic radiation. So, here just I have taken scale so this is the frequency scale ok. So, this it is in hertz so 3 into 10 to the power 6 10 to the power 8 10 12 ok. So, these the frequency scale next just below this wavelength scale.

So, 100-meter, 1 meter, 1 centimeter 0.1-millimeter, 1 micro meter, 10 nanometer, 0.1 nanometer and this is 1 picometer ok. So, wave number in terms of wave number, you are familiar with the wave number. So, in terms of wave number this is the scale. So, 10 to the power minus 4 2 10 to the power minus 2 10 to the power 0 10 to the power 2 4 6 etcetera; it is in centimeter inverse and energy it is in joule per mole. So, thus this scale is 10 to the power minus 3, 10 to the power minus 1, 10 to the power 1, 10 to the power 3, 5, 7 etcetera. So, this way just I have taken scale; now as far just I can I can yes electromagnetic radiation in different range of frequency or wavelength or wave number or energy.

So, as the higher wavelength means lower frequency, this is the higher wavelength you see 10 to the power 2-meter 100 meter or smaller energy 10 to the power minus 3 ok. So, here this 100 micro 100 meter to say this 1 centimeter; so, in this range of radiation electromagnetic radiation having frequency or wavelength or wave number or energy in this range, so, this called the radio wave or radio frequency, radio wave electromagnetic wave, then this next range of frequency wavelength or number or energy. So, this is called this in this range if electromagnetic waves in this range then that is called micro wave, then next range it is called infrared, then next one is called visible an ultraviolet range ok, ultraviolet ray visible ray means this our light which is visible to us. So, visible and ultraviolet ray in this range and X ray next range is in this range that is electromagnetic radiation is called x ray and the next range it called gamma ray.

So, gamma ray have the highest higher frequency or higher energy of course, the it is lowest wavelength. So, X ray wavelength in this range is 10 nanometer to 0.1 nanometer means one angstrom in this in this X ray ok. So, microwave it is wavelength this range is 1 centimeter to 0.1 millimeter or 100 micrometer ok. So, infrared that is in this region 0.1 millimeter to 1 micrometer, but sometimes they overlap ah, but still we can distinguish, whether it is it is microwave or it is infrared, that that we can distinguish although the same wavelength, but we can distinguish them, distinguish them. Similarly, this x ray and gamma ray they overlap in this range ok, but for same frequency or same

wavelength. So, it can be X ray or it can be gamma ray so either will tell X ray or gamma ray so that that we can tell only seeing the source of this radiation.

What is the source of this radiation? So, source for gamma ray is different than the source for x ray. So, this is the broad distribution of electromagnetic radiation and this radiation are called in different name, depending on their frequency or wavelength or energy. So, this lower wavelength is gamma ray and higher wavelength highest wavelength is basically radio wave. So, what are the source of this radiation of different different kind? aAll tough all are electromagnetic waves, but they are given different name, basically based on their source from where it is coming. So, radio is source of radio frequency radio wave. So, source for radio wave is basically here this energy changed due to reversal of spin of a nucleus, it is NMR nuclear magnetic resonance nuclear magnetic resonance NMR ESR electron spin resonance.

So, NMR ESR nuclear magnetic resonance electron spin resonance. So, this is the source of the radio wave although it is electromagnetic wave, but it is called radio wave and the source of this radio wave is basically, the energy change due to the reversal of nuclear spin or electron spin. So, here just this nuclear spin say it is in these direction. So, if it is changed from this direction to the other direction so because of the change of these because of this reversal of these nuclear spin then there will be change of energy. So, that change of energy will come out as a radiation similarly for reversal of the electron spin also it will give there will be change in energy for these 2-state and corresponding energy will come out as a electromagnetic radiation and that radiation will be called radio frequency or radio waves.

So, then micro waves so what is the source of micro wave? So, source of micro wave is basically here we are telling that rotation of molecules rotation of molecules is the source of micro wave. So, that is what will study in this course then infrared. So, radiation electromagnetic radiation in these frequency or wavelength range, so, which is called infrared so source of infrared, is basically vibration of a molecule ok. So, this infrared wave, we get this due to the vibration of the molecule. So, this also will study in this course and then visible and ultra violet. So, this radiation this radiation comes due to energy change of balance electron of atom or molecule ok. So, basically electronic transition in atom or molecule gives this visible and ultra violet radiation so these also will study.

So, in this course basically in this course basically will study the rotation of a molecule, vibration of a molecule and electronic transition in a molecule ok. So, they if different they give electromagnetic radiation of different wavelength or frequency and they are called microwave infrared and visible ultra violet visible an ultra violet that is ok; so, this basically our subject so that we will study in molecular spectroscopy or physics of molecules. So, from there so this will know about this will know more and of course, this the this next range is X ray source of X ray is X is basically the energy change due to the rearrangement of nucleus rearrangement of;

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Ah. So, rearrangement of basically the core electrons ok, or it is better to tell that, source of x is basically energy change of energy change of core electrons. In atoms or molecules ok, that the source of X ray, and source of gamma ray is the energy changed due to the rearrangement of nucleus ok. The gamma ray know this nuclear phenomena. So, rearrangement of nucleus means from one nucleus, if it beats gives 2 nucleus. So, then there would be radiation. So, this basically rearrangement of nucleus gives the change of energy, and that will give gamma ray ok.

So, so this you know about the radiation different kind of radiation radio frequency microwave, infrared, visible ultra violet, X ray, gamma ray ok. All are electromagnetic radiation, and they are more or less, they are frequency or wavelength, distribution is like this. And here additional things, I told you about the about the source of each electromagnetic radiation. Each electromagnetic radiation whose has particular name. And why I had discussed this one, because whatever this molecular spectroscopy we are going to study. It is related with a electromagnetic radiation; that is basically microwave, infrared and visible or ultra violet range. So, that is what we will study in this course.

So, now, basically will study the; will start our study in molecular spectroscopy, that is basically this what is ah; first we see the you have a molecule the rotation of a molecule rotation of a molecule.

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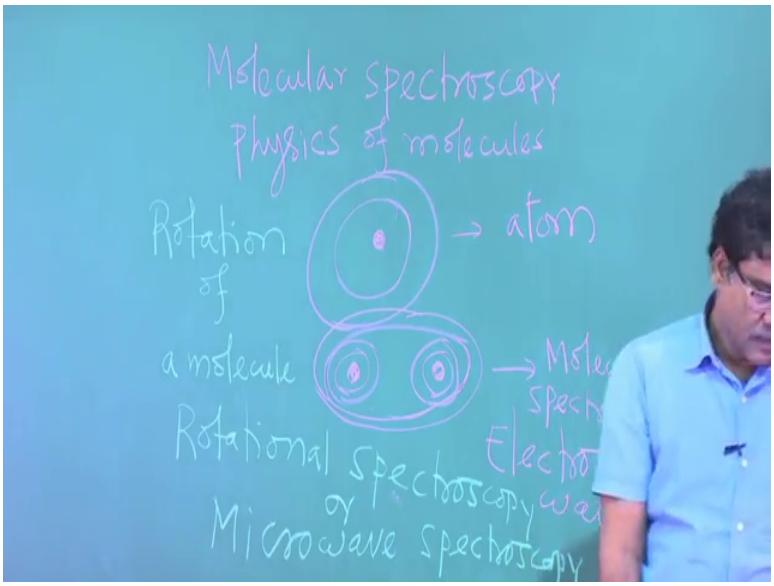

So, this is called rotational of spectroscopy or microwave spectroscopy. So, rotational spectroscopy rotational spectroscopy, rotational spectroscopy, rotational spectroscopy or it is also called microwave spectroscopy, so, why it is called microwave spectroscopy that that you understand. So, that is why I describe the electromagnetic radiation range of electromagnetic radiation, so this is also called microwave spectroscopy ok.

So, this microwave it is called microwave spectroscopy, because this microwave it is electromagnetic radiation this comes from the rotation of a molecule. So, so we have different; so, let us see this, let us see this; this let us see this molecules.

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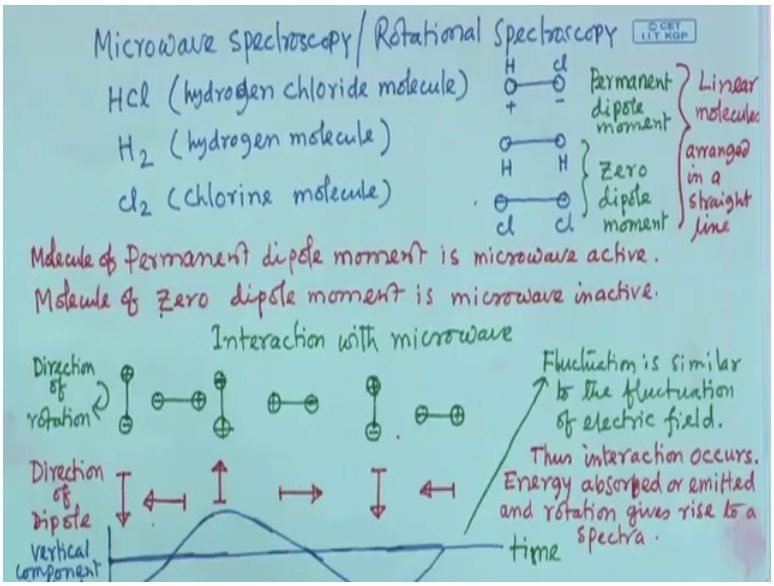

So, let us say this HCl it is a molecule. It is a diatomic molecule right. So, this it has one hydrogen and one chlorine ok. So, hydrogen molecule is 2. So, this is basically hydrogen atom, 2 hydrogen atom is separated by distance. So, similarly chlorine molecule so, 2 chlorine they are this all HCl H 2 cl 2 these are basically molecule fine. So, so what is the difference of these molecules? This all 3 are diatomic molecule, right? Now HCl there is a difference in HCl or H 2 or cl 2; so, HCl basically it has permanent dipole moment. Because to charge different charge are this 2 charge are separated with a distance. So, equal charge separated by not different charge equal charge separated by distance so it form a dipole moment. So, it has permanent dipole moment ok.

And this is this molecule H 2 molecule or cl 2 molecule ok. So, this molecule does not have dipole moment permanent dipole moment, so it has 0 dipole moment. So, molecule, then; now molecule differentiate with respect to this whether they are they have permanent dipole moment, or they do not have permanent dipole moment ok. So, some molecules will have permanent dipole moment. So, this is one group and some molecule have will have this 0 dipole moment. So, this is another group. So now, in microwave spectroscopy they are so, this is very important for this for this difference. So, basically these molecules which have the permanent dipole moment, so, they are called microwave active molecule microwave active molecule and those molecule which are not having permanent dipole moment. It is they have 0 dipole moment.

So, that molecule is called basically microwave inactive molecule microwave inactive molecule ok. Means, neither they will they will emit microwave nor absorb microwave. So, so only microwaves spectra we can see either emission spectra or absorption spectra; means, either the molecule emitting spectra emitting or absorbing electromagnetic radiation or microwave ok. So, so basically the molecules which are having the permanent dipole moment that is called microwave active molecules. And only these molecules will give microwave spectra ok; either emission spectra or absorption spectra right.

So, microwave why it is gives this microwave radiation because this if you see; this a molecule which is having permanent dipole moment ok. Now this rotation of this moment of this of this molecule basically ok; so, if this is the direction of rotation this is the molecule so it is direction of rotation due to the rotation it is direction which direction of dipole direction of dipole will change. So, direction of the dipole is basically from positive charge to negative charge. So, this the direction of dipole then it is changing so this will be another direction. So, it is rotating it is changing so these are different stage we have shown ok. So, during rotation during rotation; so, from this position it will rotate come here in this position; that means, is dipole moment was in this direction, now it is in this direction, then this direction, then this direction, then this direction so this a changing; so, dipole now as if dipole is fluctuating ok. So, dipole is fluctuating so this fluctuation of dipole with time fluctuation of dipole with time.

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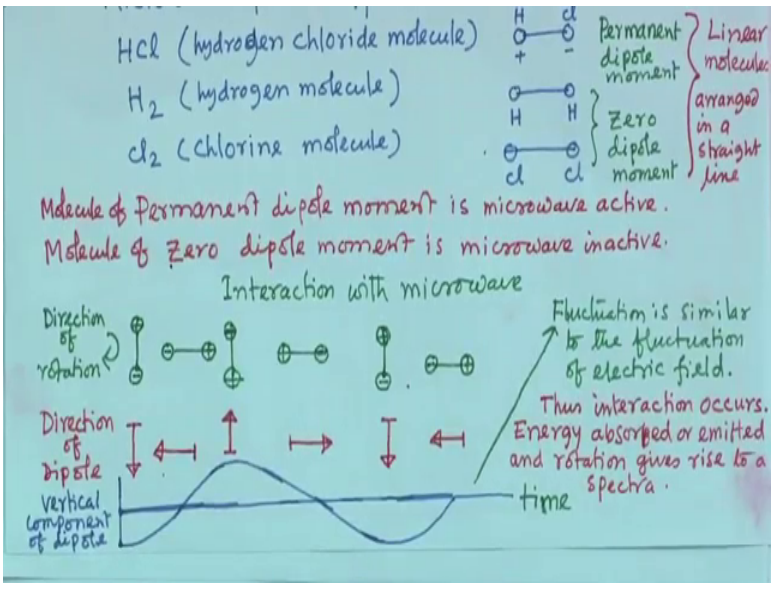

We can show if you just take the particle component of the dipole ok. So, this is in this direction so it is magnitude is maximum magnitude is maximum and ah, but it is negative direction so this magnitude and the value. Now it is rotating so changing it is value changing when it is in this direction. So, particle component is 0 so this is 0. So, here you can positive direction. So, particle component is maximum then again 0 then maximum in negative direction then again 0. So, as if this is the fluctuation of dipole moment dipole moment with time. So, these periodical variation of these dipole moment due to the rotation of the molecule; that means, molecules rotation of the molecules is basically, giving the giving the periodical change of dipole moment as if this is the. So, if any change periodical change of charge dipole moment. So, gives basically radiation it emits radiation and this radiation ah, whatever will get due to the rotation of the molecule due to the rotation change of the fluctuation of the of the dipole moment so that radiation is basically microwave.

So, this microwave, whether microwave whether this molecule will emit or it will absorb when it is absorbing then we tell the interaction of the interaction with the microwave ok. So, interaction of microwave with the meter inform of molecule so that is basically that absorption or emission whatever or interaction with microwave that is basically due to the different states rotational states of the molecule. So, I will stop here so will continue with this discussion in next class.

Thank you.