Chemistry II: Introduction to Molecular Spectroscopy

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Lecture 1
Electro Magnetic Radiation
Oscillating Waves and Electric and Magnetic Fields

Welcome to the lectures on Molecular Spectroscopy. In this week which is the first week we have a few introductory concepts and the first lecture is on basic properties. We should know of the electromagnetic radiation.

Now spectroscopy is the introduction of electromagnetic radiation with matter and the properties of electromagnetic radiation such as the electric field, the magnetic field, their variation in time and how the wave lengths and the wave frequencies of this radiation are connected to the energies of so one is the focus of this lecture.

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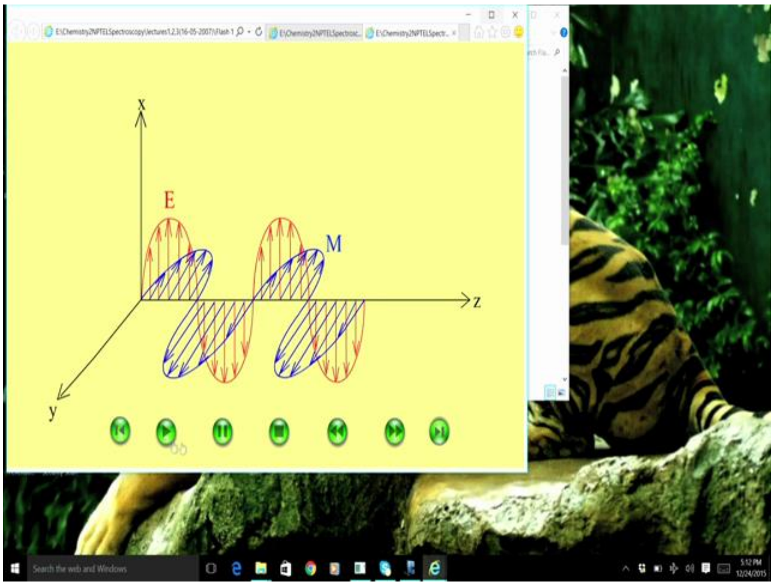

So, let me first introduce you to the oscillating electric and magnetic fields as waves. So, what we see here is an axis system X Y Z rectilinear in which the time dependent oscillations of the electric and magnetic fields are shown as waves in mutually perpendicular directions.

You can see that the blue oscillation is marked as magnetic field and it is in the Y Z plane the red oscillation are marked as the electric field and that is plane in a perpendicular to the Y Z namely the X Z.

Axis X Z plane and both of this waves the oscillations red and blue oscillations are perpendicular to the direction of propagation which is the propagation marked as direction.

So, electric field and magnetic fields of an electromagnetic radiation oscillate in time with a same frequency. So, this is the purpose of showing this animation and you can see that and you want to play this again you can see how the waves are shown as oscillating in time.

This is a classical picture Albert Einstein of course, came up with the theory that light is it consists of what are called the packets. The packets have specific energy which are proportional to the frequency of the oscillation. So, let us now introduce some of those terms.

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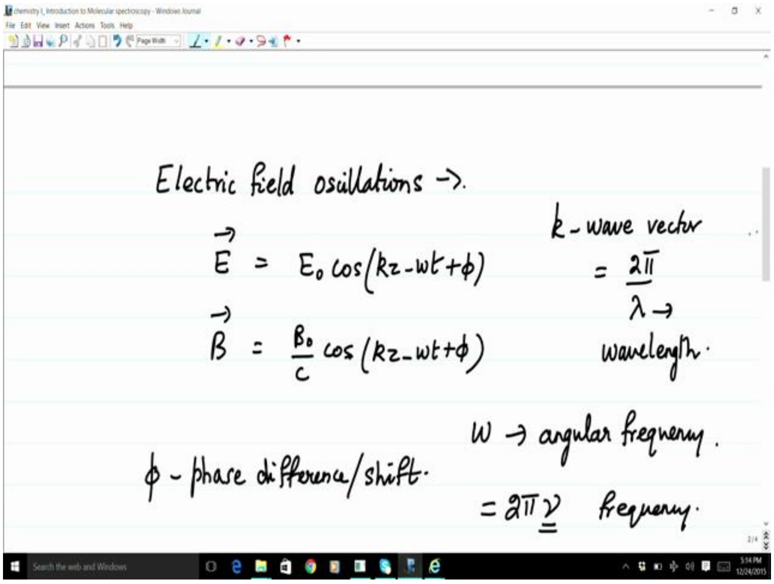

The oscillation of the electric field in time and in space is typically given by a simple harmonic oscillation namely the electric field which is a vector is given in the terms of magnitude of the amplitude of the wave E naught.

And a cosine K where K is called the wave vector for the wave and is given by the wave length of the wave we will see in that in a minute lambda is the wave length.

So, E is E naught of cosine K Z minus omega T and omega is known as the angular frequency of the wave. It as to be K as to be inverse dimension of Z which is length and omega as to be inverse dimension of T and you can see that the omega angular frequency is given by this formula 2 pie times mu, where mu is the frequency of oscillation.

The magnetic field B is given in a similar passion with an amplitude B naught by C and a cosine oscillation also given by K Z minus omega T in both cases I have put in factor called a phi which is usually a phase shift or a face difference for the waves shift that is the starting point of the wave we can determine.

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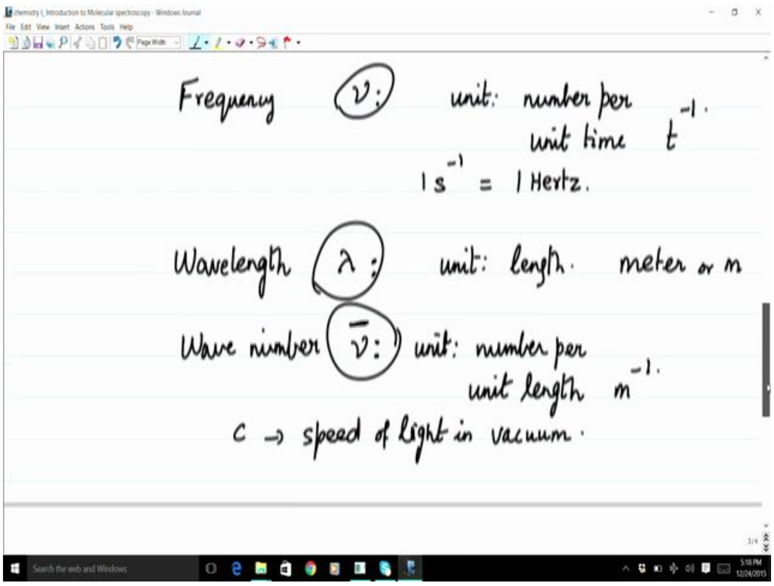

Now, there are 2 or 3 properties that I have introduced the wave length angular frequency and also introduced a unit called wave number let us see. The frequency of the wave mu is basically the number of the waves the passing point given in a unit time let us see that in the oscillation here.

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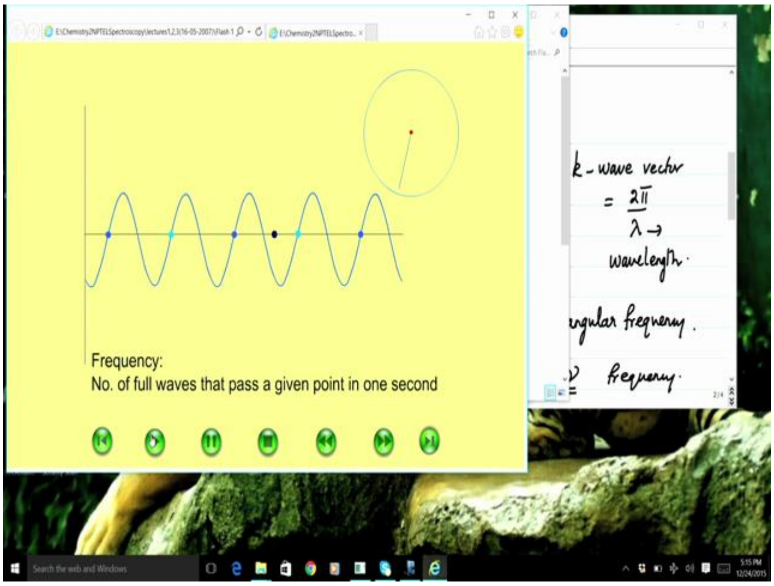

You can see that the frequency is number of waves for example, passing through this point the blue dot that you see here in a unit time. So, it is number per unit time the number of full waves is pass a given point in 1 second here, the time is in seconds and the number per second is called the frequency.

The other definition that you have to keep in mind is the wave length. Wave length is denoted by the symbol lambda and being a length as the unit of length and usually in terms of meter or sub units of meter like millimeter or micrometer or nanometer so on.

But the wave length is the length of 1 oscillation the wave number is the number of such waves in a unit length.

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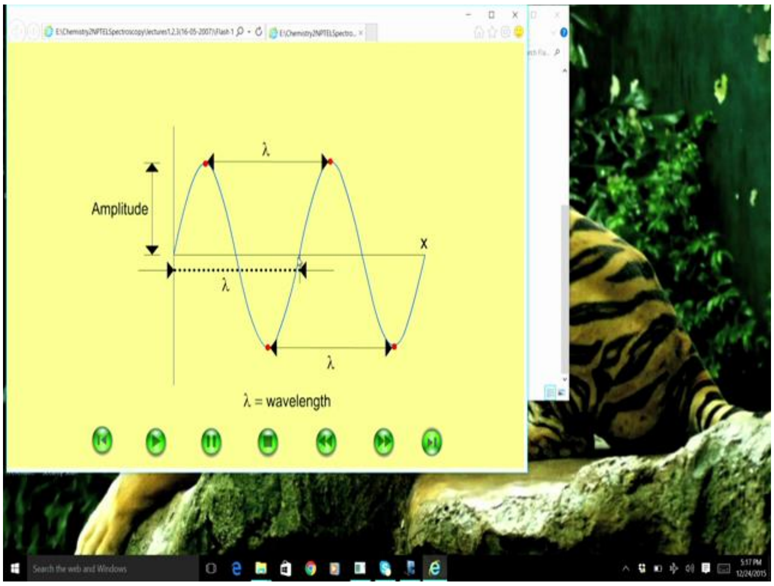

Let us see that the wave length is the length of a wave a full wave and you can see that a full wave obviously, marked by points of repeated occurrence successive occurrence for example, between the 2 cress or between the 2 turfs or between the starting point of the wave or some time amplitude being 0 or some amplitude and going through one full cycle whatever is the distance that length is called the wave length.

So, this is the lambda is the same whether it is between these times or whether it is between this points or it is between this points.

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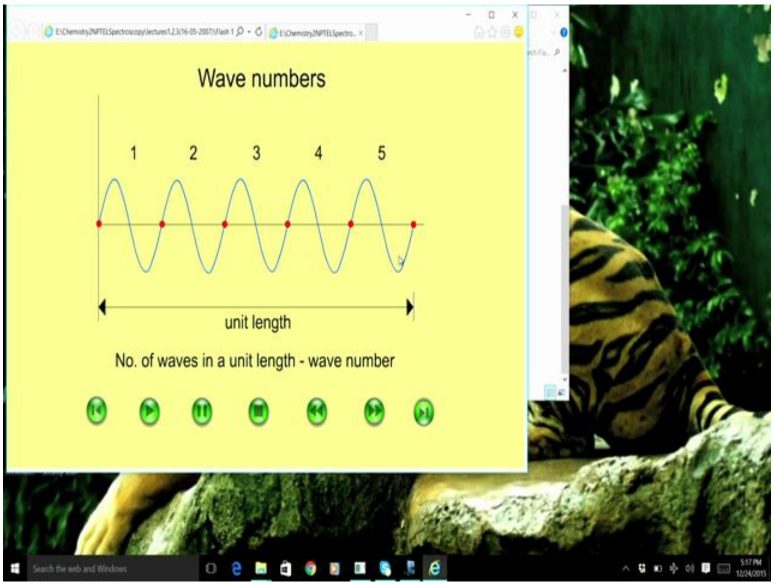

So, it is successive occurrence for it is length of 1 full wave. What about wave numbers suppose, we have a unit length marked by a distance here let us see if this is a unit length then in that length the number of waves.

So, you can see immediately wave length and the wave number or inverse of each other because one is the length of the wave the other waves how many such waves are there in unit length.

So, these are elementary ideas, but never these are important. So, we have 3 quantities namely the frequency, the wave length and the wave length which usually written as mu bar. And wave length is with the dimension numbers per unit length or with the unit meter inverse.

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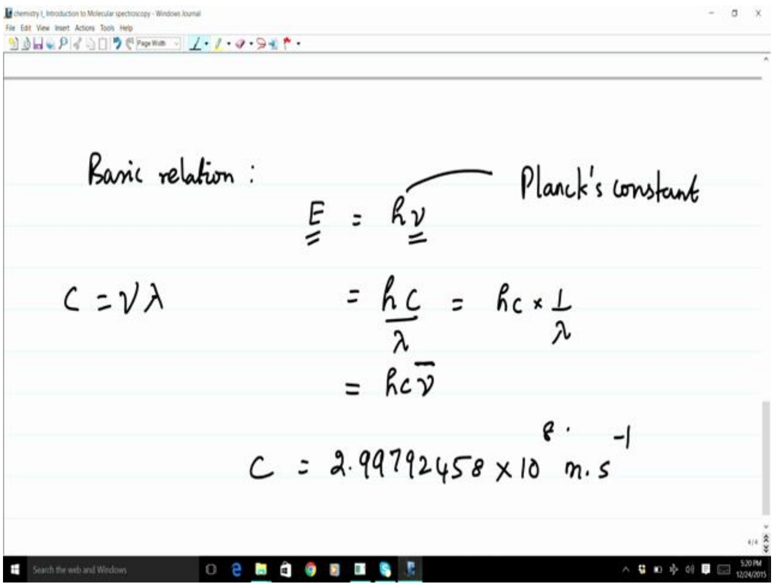

And this are connected to each other through the speed of light in vacuum in which of course, as a value C as a value 2.99792458 times 10 to the 8 meters per second ok.

That is the speed of light in vacuum and the relation between the frequency and the energy of a photon which in Einstein's formulation the electromagnetic wave is treated as a collection of packets and the energy of individual packets are the photon is given by the frequency and H is of course, Planck's constant.

And frequency and the wave length are related to each other by the speed of light C is equal to mu lambda and if you substitute for that you see that energy is HC by lambda or it is HC times 1 by lambda therefore, you can see that the energy is proportional to the wave number the energy is proportional to frequency, but the energy is inverse the proportional to the wave length.

So, this are fundamental relations in treating the electromagnetic radiation as a wave for the course on spectroscopy we shall use electromagnetic radiation with a classical property that we have familiar with that it is a wave the reason being that such an approximate formulation is sufficient to understand at fairly detail level what happens to the transitions what happens to the intensities of this spectra lines and so on.

Of course, an exact or more accurate even description of the electromagnetic radiation if it is done in the form of photons will require creations of photons (Refer Time: 10:19) of photons and so on and that is taking more into mechanics.

Therefore, the spectroscopy that would do is a combination of 2 ideas namely, the energy levels of the molecules being treated quantum mechanically and the electromagnetic radiations treated as a classically.

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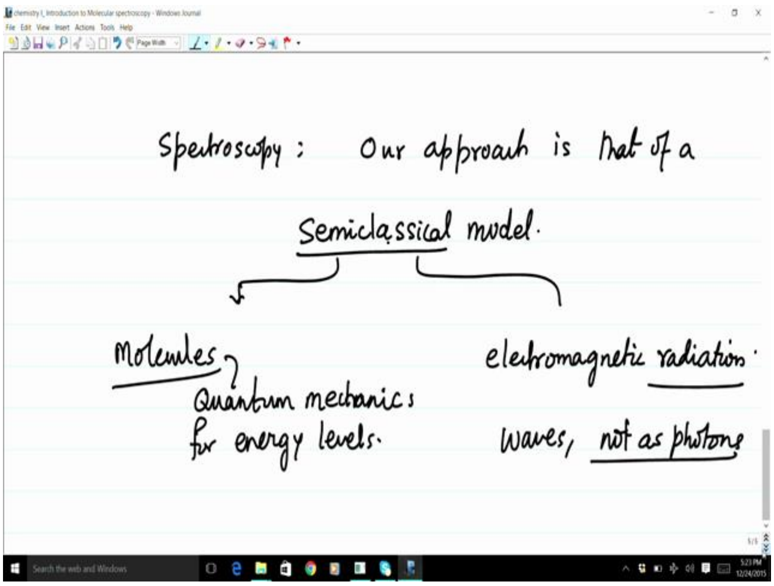

So, it is a semi-classical model that we will have. Spectroscopy our approach to spectroscopy is that of a semi-classical model semi-classical obviously, implies that it is both classical and not classical.

What is not classical? We treat the molecules as a quantum mechanical system and therefore, we study the molecular energy level by solving the quantum mechanical equation namely the showing equation.

And therefore molecular energy levels are treated using quantum mechanics. The semi-classical part the classical part of the semi-classical is that of the treatment of electromagnetic radiation as consisting of waves of oscillating electric field.

And oscillating magnetic field and not necessary as photons and then invoking the quantum electro dynamical theory of the electromagnetic radiation, we do not do that is for much more advanced work and for the current spectroscopy model and this for probably couple of other courses in chemistry the semi-classical model is sufficiently accused please remember molecules by quantum mechanics radiation by classical mechanics.