Chemistry I – CY1001
Introductory Quantum Mechanics and Spectroscopy
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Lecture - 01
Welcome

Welcome to this course, the first part of the course in Chemistry which is Introductory is on atomic structure and spectroscopy. What we will do in the limited period of this 6 to 8 weeks is to introduce the basic theory and methods which are used to understand atomic and molecular structure and also to explain what we see in the experiments namely in spectroscopy. Spectroscopy is the interaction of radiation with matter and also provides the experimental tool and verification for all the things that we have understood so far in molecular and atomic quantum mechanics.

Being an introductory course meant for the first or second year students entering the college, I would keep the mathematics to a reasonably low level; however, I do not want make any approximate statements as far as possible, I want to make the statements as quantitatively as I can. And there are obviously, exercises and assignments for you to practice that and then you can have this also discuss with your teachers in class in some sort of the reversed class mode to have the teachers interact with you and solve problems for you.

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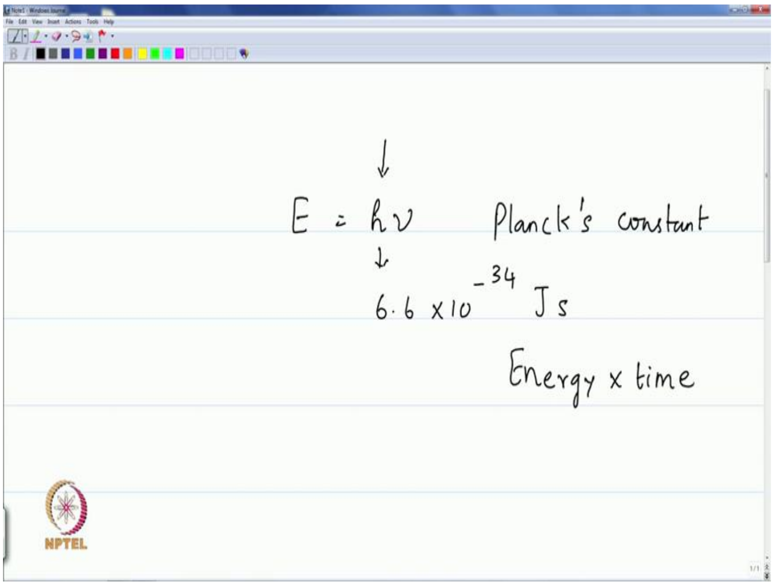

The only way to learn the subject is by solving as many problems that is by learning; by doing and I would very strongly recommend that you solve every problem that is proposed in this lecture series, every assignment that is given and also every in class exercise which is provided along with the lectures.

The first introduction to quantum mechanics is something that needs a little bit of elaboration as to why it is important. Almost at the turn of the last century to be precise 1900 Max Planck came up with the hypothesis that energy emitted or absorbed by the material bodies does not happen in a continuous fashion. But that it is a emitted in packets, quantas and he came up in this famous formula for the energy in terms of the quantas and in terms of the frequency of like that gets emitted, by the formula E is equal to h nu; where nu is the frequency of the variation that gets emitted or the radiation that gets absorbed by the material bodies and he introduced a constant which was not known until then and called this as the Planck's constant.

He did not call it; all the others did since it was his fundamental contribution and he proposed the value somewhere around 6.6 to 10 raise to minus 34 Joule second and since this is energy and frequency is per second, the dimension of the constant or the Planck's constant is energy into time. There are other ways of decomposing these dimensions but after Plank introduced this, it was not something that everybody accepted it as is, but they thought that with his prescription of the discretization of the transaction of energy by the material bodies; he could explain at that point of time very satisfactorily what was known as the black body radiation phenomenon, which could not be explained by any classical to mechanical methods.

Just about 5 years later it was Albert Einstein who threw in the next tantrum if I may say so to the whole field of physics with his hypothesis that or his proposition that light itself consisted of packets of energy. If you recall elementary physics Newton many many years ago, I mean hundreds of years ago proposed that light consists of corpuscles or particles particulate, that was disputed later by Huygen's and many others, through the experiments of diffraction, interference and many well established physical experiments and they proposed to that light had to be a wave. Later the fact that light was a wave was further generalized by Maxwell through his theory for electromagnetic radiation in which he considered light to be part of the general field called the electromagnetic radiation in which electric and magnetic fields oscillate in time.

So, the property that light is a wave was well established for more than 200 years, but then Einstein in explaining the photoelectric effect of the emission of electrons by metals, when light falls on the metals.

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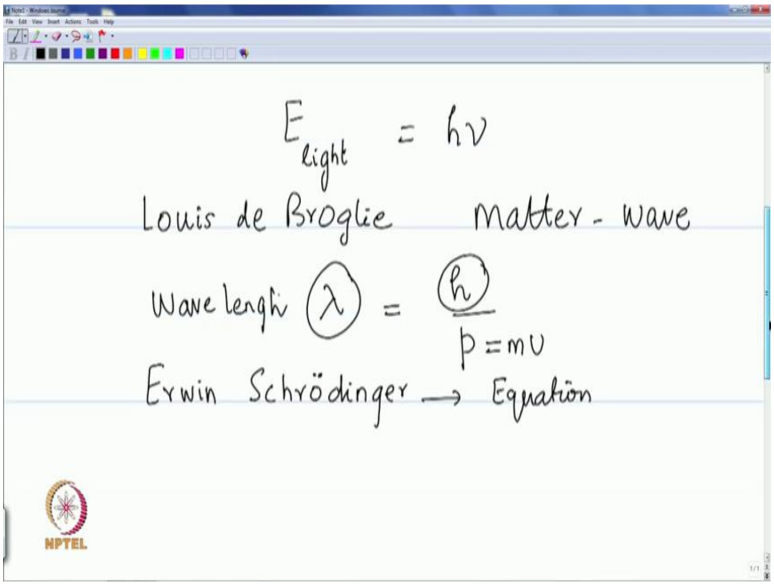

He came up with this proposal that light itself consists of packets of energy and he used exactly the same formula, but Plank had except to that now I will put the subscript light and the packet of energy also is given by this formula that h nu; where h was the Planck's constant which was introduced by Max Planck 5 years before that and nu is the frequency of light. So, there was this difficulty that how can light be both wave and particle and this discussion continued for some time and it was Louis de Broglie who added some more light into this whole process of description; namely that all material particles, which are in motion can be ascribed with a wavelength. In addition to your momentum which involves a mass and the mass is of course, localized; therefore, all material particles which are localized while they are travelling, while they are moving can be associated with a wavelength and he called it as the matter wave.

And this process he introduced the wavelength lambda to be again involving the Planck's constant and the momentum of the particle, this is for particles which travel not with the speed of light, but much less than the speed of light; which you can write as the mass times the velocity. So, here is again the Planck's constant and this idea that particles in motion can actually be associated with a wavelength, now brought into question by someone who would contribute to the most fundamental equation of matter for the next 100 years by Erwin Schrodinger.

Schrodinger asked himself the question what is the dynamical equations governing such matter waves would be, why this question? Because, Newton and many others had described the planetary motion and the motion of microscopic particles through their equations of motion, the dynamics in time that is how things change in time. The dynamics was well known to Newton's equations of motion. Then the dynamics of electromagnetic radiation, I mean the properties of electromagnetic radiation where; obviously, described by Maxwell known as the theory of classical electromagnetism.

So, there were theories for the time evolution of waves and the time evolution of particles, but things which behave particle and wave like; is there a separate dynamical equation that will govern their evolution in time and Schrodinger came up with the proposal and the answer which became the most famous equation of the last century called the Schrodinger equation and I will write that out.

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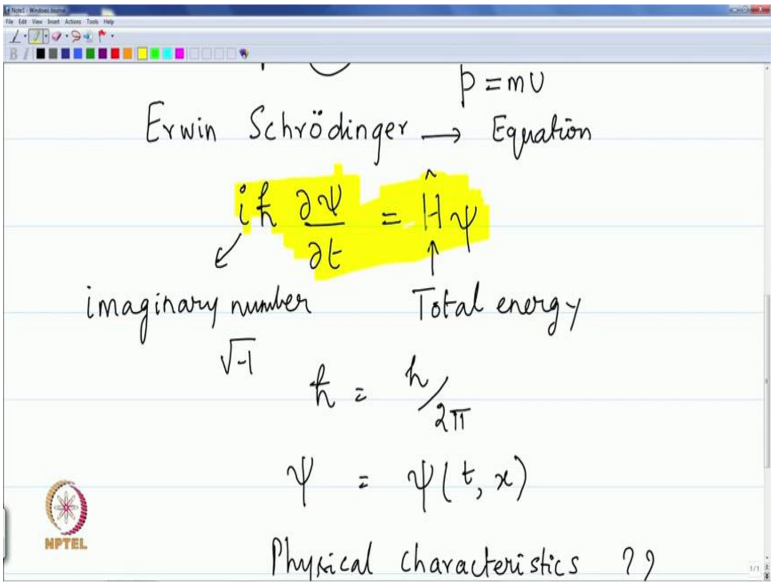

Schrodinger equation comes up with a function psi, which is a function of time and a quantity called the Hamiltonian or the total energy of the system and it involves the imaginary number; square root of minus 1 and h bar is again Planck's constant h divided by 2 pi. Schrodinger proposed this equation as the equation that the matter waves would satisfy and he proposed the function psi as a property of the system and since it is a property which describes, how the system evolves in time; psi itself is a function of time.

But in addition to time it is also a function of the position or the momentum, but not both. The x here present position in one dimension or one dimensional motion, but if the motion happens in three dimensions; it is a function of all the three positional coordinates of that system or the particle, but it is also a function of time. Schrodinger proposed this wave function and then when this question was asked, what does this wave function mean? Even he had difficulty explaining the physical property or the physical characteristics of the wave function or nature.

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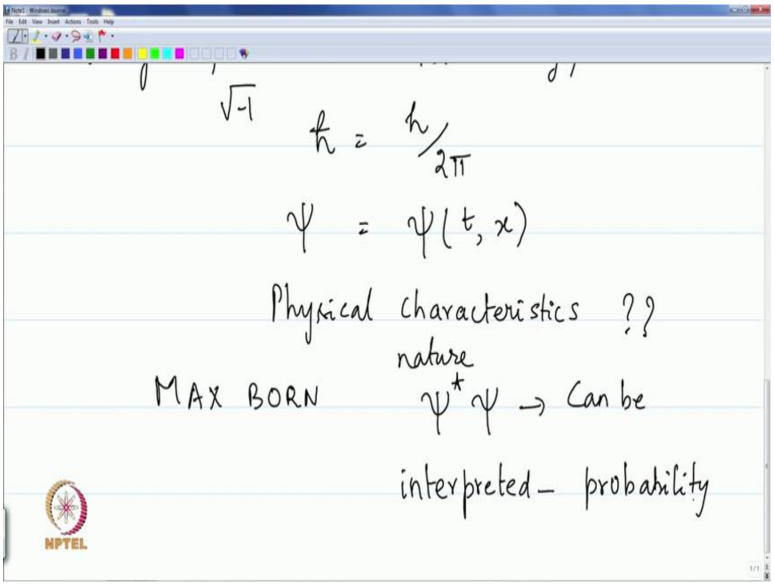

What is it? In fact Schrodinger made a mistake, his interpretation was proved to be wrong and later it was professor Max Born who came up with the correct interpretation that most of us accept today that it is not the wave function which is important given that this equation is an equation containing, see this particular one that you have here, let me highlight it. See this particular equation which has the total energy on one side and it has a wave function on the other side, but it also contains the imaginary number and therefore, it is possible that the wave function psi itself is imaginary or complex and if it is complex then we do not have a physical interpretation for the wave function itself.

But it was Max Born who said, it is not the function psi, but it is a complex conjugate times the wave function itself, the product, that can be interpreted through probability statements. It is associated with the probability of something; we will see all of this in this whole course.

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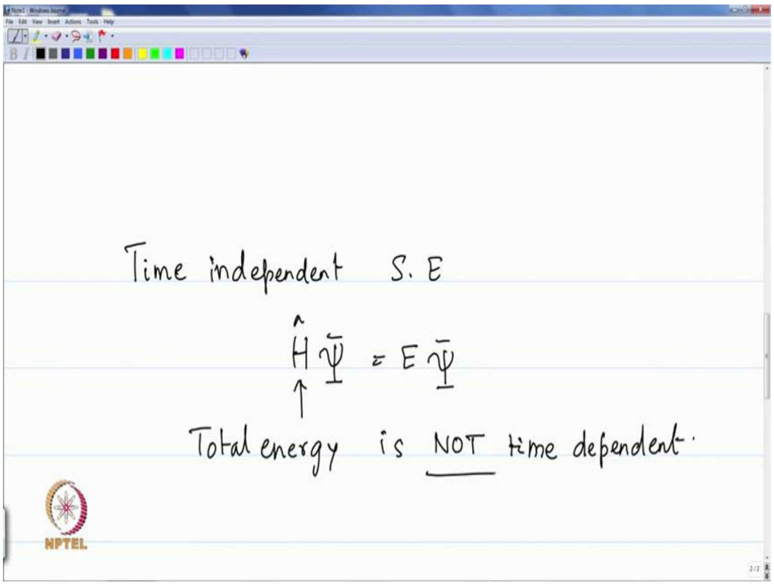

In the entire course it would be nice for me to actually solve the time dependent equation, but I am not going to. I would limit myself to a much smaller subset of the Schrodinger equation known as the time independent Schrodinger equation, which is given by the symbol H, let me write it with a different wave function psi capital as a constant times psi and this is time independent in the sense, the Hamiltonian or the total energy associated with that system is not time dependent or it is time independent.

If radiation interacts with matter for a brief time as we do in spectroscopy during the interaction period, the system total energy is dependent on time because the radiation itself is an oscillating electric and magnetic field in some approximation in the wave approximation. Therefore, the Hamiltonian (Refer Time: 14:44) principle be dependent on time or we may introduce a force for a short period, a changing force. Therefore, the Hamiltonian which represents the total energy of the system may actually depend on time, but we will not consider those cases, we will consider those problems in this particular course of short 15; I mean 2 weeks or 8 weeks or 10 weeks period. We would study only the time independent Schrodinger equation and this would be done with simple model problems in the entire course models.

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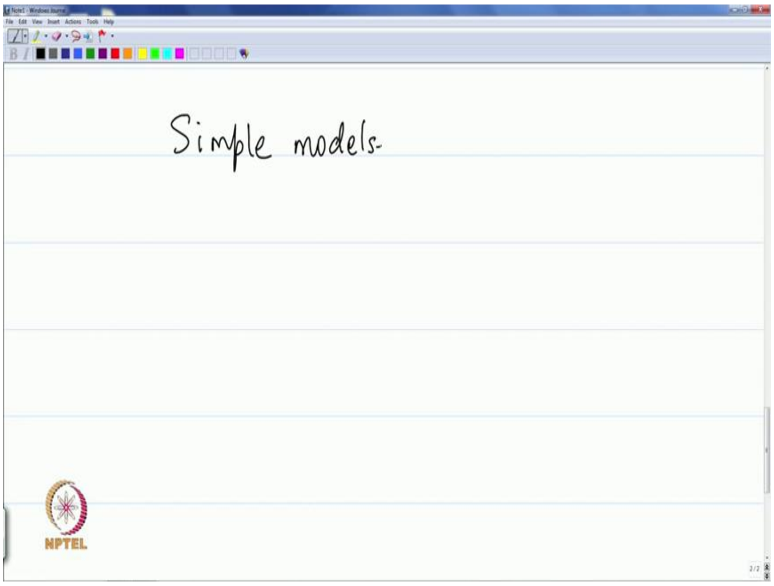

And these models will later be associated with the chemical systems in order to give you the feel for why chemists are interested in it. I welcome you all to this course and I hope that you will enjoy the learning process in the next 8 weeks or so, but please do answer all the assignments, please do attempt all the assignments, please do answer all the questions which are discussed either in your class related to the subject or given to you for your own attempt. Without solving those problems, you will not even be able to appreciate what all of this is about and I wish you all the best. We will continue that in the next lecture.

Thank you.