Atomic and Molecular Physics

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Lecture - 07

Structure of an atom (Contd.)

We will continue our discussion on structure of an atom. So, so far what we have learned is that atomic nature of matter, second is constituent of an atom that we have seen the electron, proton and neutron right, and then third is we started about the structure of an atom right.

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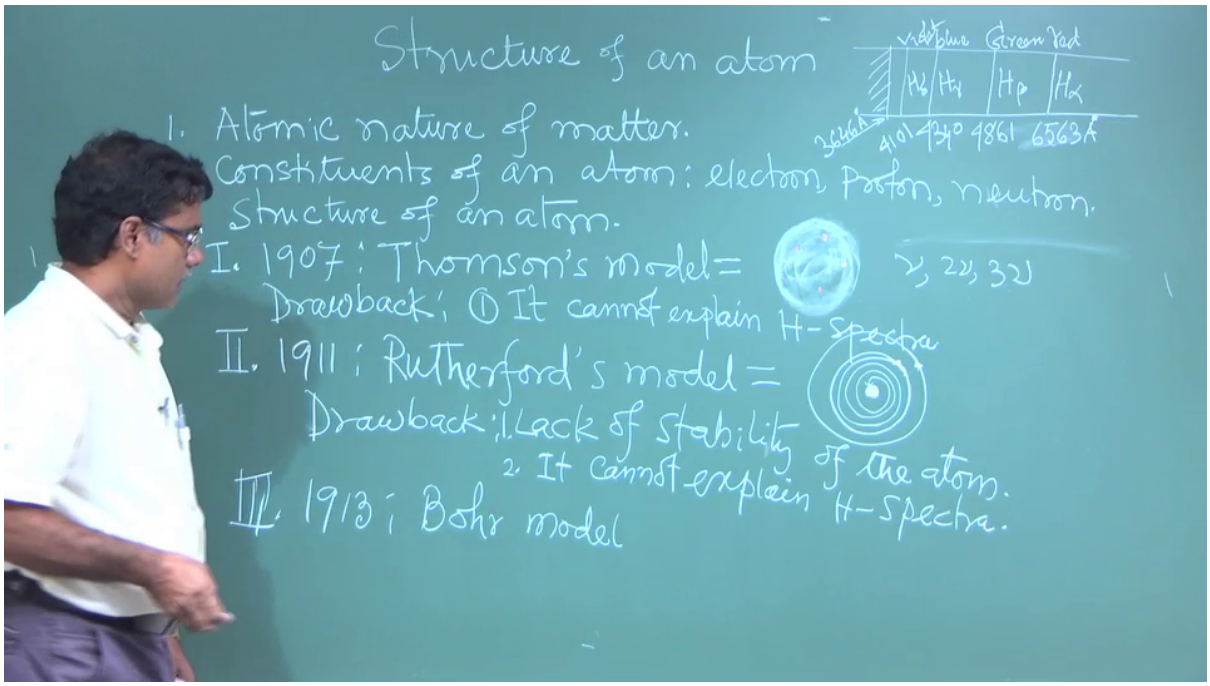

So, first we have seen in 1907 Thomson's model higher it was considered that these positive charge is distributed in a sphere and electrons are embedded at definite position or a particular position in this positively charged sphere. So, but this model was failure because what was the drawbacks of this model, drawbacks of this model basically it

cannot explain, it cannot explain atomic spectra the simplest atomic spectra that is I told that hydrogen I can draw here hydrogen spectra, the simplest spectra, these are the brightest spectra lines. So, this wavelength is I think 5 6 3 6 5 6 6 3 angstrom sorry; 6563 angstrom, 6563 angstrom is basically red colour, red colour line. And then next one was 4861, 4861 angstrom, the other one 4340, 4340 angstrom and 4101 this one 4101 angstrom and this limit that was 3646, 3646 angstrom right.

So, that was the spectra this colour was is a red green blue violet; red green blue violet and these are the very bright colour lines and this is also you know many people called it as the H alpha line, H beta line, H gamma line, H delta line right.

So, atomic structure we are looking for explaining the atomic spectrum at least it is simplest one hydrogen spectra. So, this structure should be such that it should explain this hydrogen spectra. So, in that taking that motivation, this depend model was proposed and it was cancelled due to the lack of lack of the curability of explaining the hydrogen spectra. So, it cannot explain hydrogen spectra right why, because this it was considered it was postulated that this electrons at a definite position it is not a rest, it will oscillate, it will oscillate and it will radiate.

So, that radiation is basically is will get as spectra lines, but hydrogen atom has only one electron see can oscillate only at a particular frequency. So, we should get only one line or we can or you can oscillate actually at a particular frequency and with higher harmonics. This is frequencies nu then in other frequency can be 2 nu, 3 nu, etcetera. But this higher harmonics higher frequency lines should be very weak, but in hydrogen spectra you have seen this all these lines are very bright as well as there is no such correlation with the among this spectra lines right it is not, this frequency of this line is not double of the other one or triple of the other one. So, it was the drawbacks of this model, so this model was not successful, then in 1911 Rutherford's model, Rutherford's model. What was that model? So, Rutherford told that this actually experimentally found that all mass concept in a very small value in the atom.

So, he considered that is the nucleus and negative charge electrons. So, electrons will revolve in orbit around the nucleus just much alike to the planets revolving surrounding the sun in particular orbit right. So, similar to planet solar system, electron these equivalent to the planet and nucleus is equivalent to the sun. So, that was the taking that

similarity he proposed that type of model. So, nucleus all mass are here and electrons, electrons will rotate in different orbit right. So, what problem for us that when electron charges particle is rotating, so it is accelerated, any accelerated charge particle it emit radiation. So, when it will emit radiation its velocity will decrease. So, as if, its velocity will decrease and is it will follow the spiral path and it will finally, fall in the nucleus. So, negative charge and positive charge they cannot stay together. So, atom will destroy will get destroyed.

So, the drawbacks of this Rutherford model was, lack of stability of the, lack of stability of the atom right and then also that it cannot explain the hydrogen spectra, atomic spectra, it cannot explain atomic spectrum it is a hydrogen spectra. So, next actually started to discuss that next model is basically Bohr model in 1913 Bohr model. So, Bohr was basically the student of Rutherford he was working Rutherford's laboratory, that in last class I started to discuss that Bohr model. So, let us continue. So, Bohr as I told that Bohr took a Bohr step considering the combining the Rutherford model, combining the Rutherford model.

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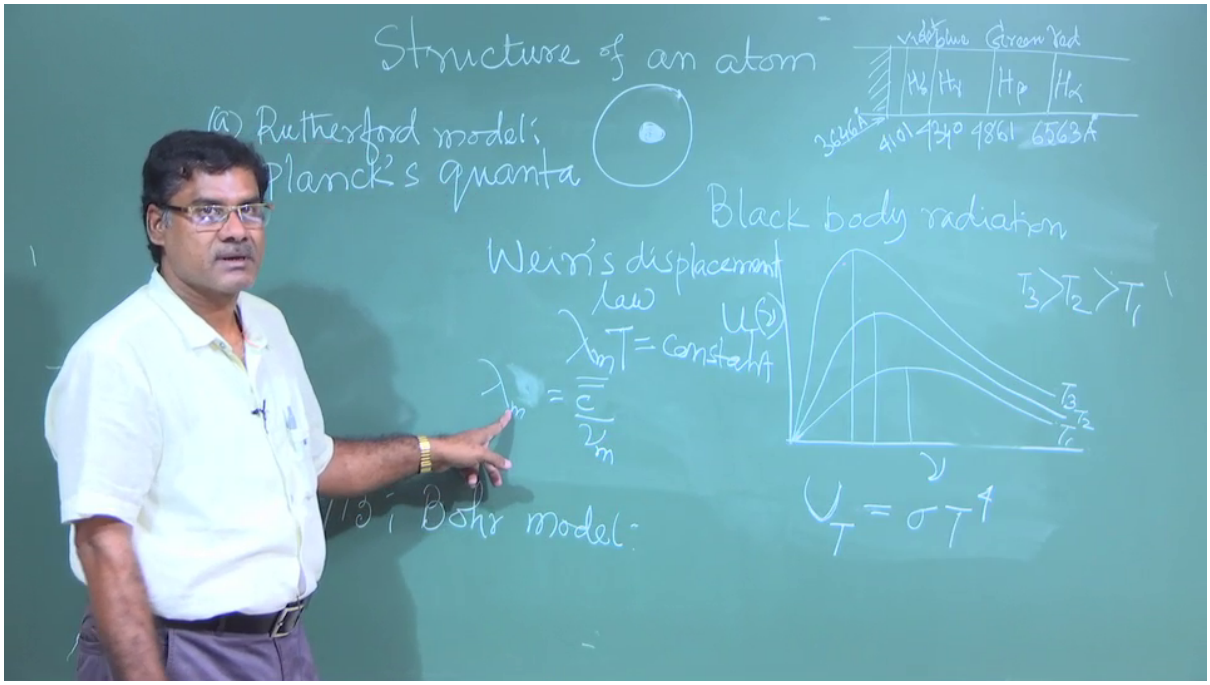

That was basically these electrons will rotate electrons will rotate in orbit like planet surrounding the nucleus. So, he considered that Rutherford model and second he considered Planck's hypothesis of quantization or Planck's quantum we tell Planck's

quanta. What was that; Planck's quanta? So, actually that time it was very this black body radiation black body radiation it was experimentally it was found that if I plot if I plot frequency verses this energy density. So, say energy density U at a particular temperature and then if I write nu this in black body radiation this energy of unit radiation energy of unit radiation or unit time and at a particular temperature. So, these distribution is like this sorry, at different temperature T 1, T 2, T 3. So, T 3 is greater than T 2 is greater than T 1 right.

So, higher temperature the density increases and it was found that this maximum density at a particular frequency. So, with temperature this decrease nu max frequency correspond to the maximum intensity or density, it decrease, it decrease, in case of wavelength it increase maximum intensity at that at a wavelength it is increase. So, that was experimental observation and then it was trying to explain it was trying to explain a long time. So, actually to explain that once it is a Stephen's law you know this is a, it is a I think that is total energy U T it is for all wavelength, it is sigma T to the power 4 and then I think this Wein's displacement law, Wein's displacement law lambda m into T equal to constant, what nu corresponding this lambda m maximum density at this wavelength. So, with temperature it shifted.

So, its lambda m become higher at lower temperature, just opposite frequency is higher at sorry frequency is higher nu m maximum intensity or density is higher at this frequency, so this frequency into temperature is constant. Not into temperature, so this nu c by lambda m, c by lambda m. So, in terms also that you one can convert to nu is; nu is basically you know lambda, lambda nu equal to c. So, one can replace lambda m equal to c nu c nu. So, this nu will be I can write nu m corresponding this maximum. So, nu m can be replaced by c by lambda m lambda m can be replaced by c by nu m. So, that way T by then it one can write T by nu m equal to constant. So, anyways, Wein's displacement law it is either in terms of frequency or in terms of lambda one can write.

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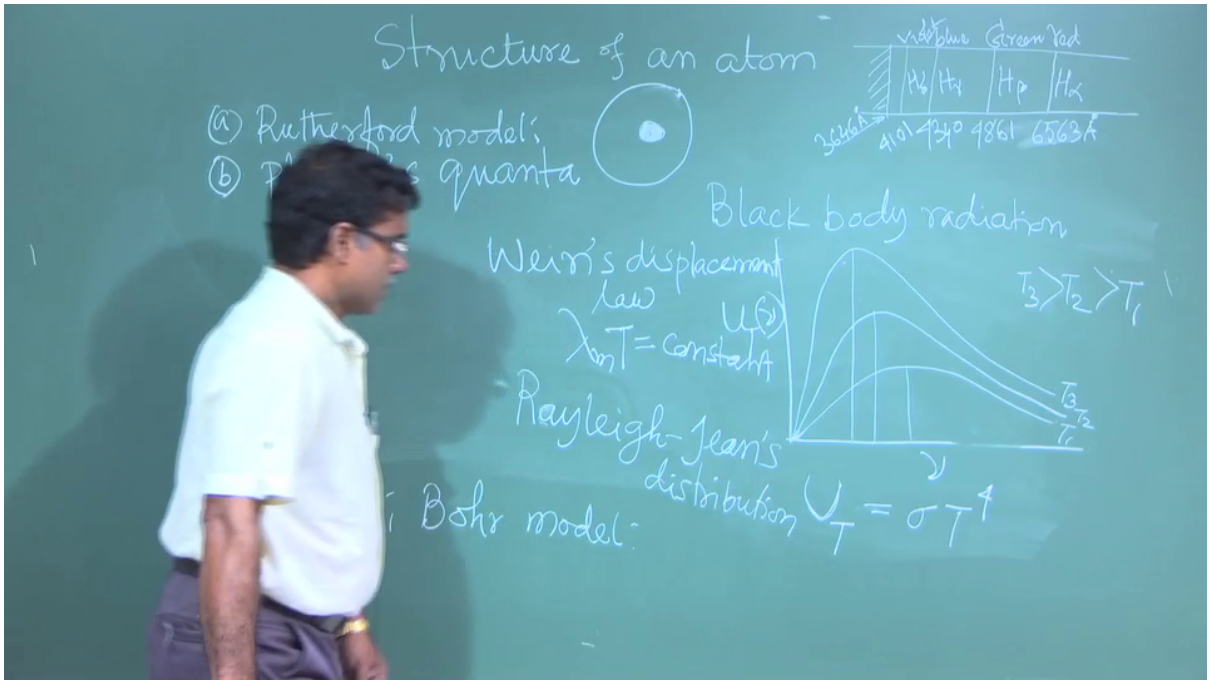

So, that was the Wein's displacement law and then Rayleigh-Jeans distribution, Rayleigh-Jeans distribution, Rayleigh-Jeans distribution of this of this of this spectral energy. So, basically this it is distributed following this curve, following this curve, Rayleigh-Jeans they try to if theoretical try to find out the formula to explain this curve, but all atoms. So, these are basically is it was not able to completely explain this curve. So, partly it was able to explain. So, this theory was not complete.

So, then the Planck's, then Planck's was able to explain this curve, so I will not go into details. So, it was he was able to explain this carve because he postulates that he postulates that that is actually black body radiation. So, this radiation is coming from the surface of the cavity something surface there are atoms there are electrons. So, oscillation of these atoms are electrons that basically emit radiation and that radiation feel the cavity and that is the way if to basically black body radiation and this they their distribution like this. So, he postulates that this oscillation of this electrons or atoms on the surface of the cavity it is not continuous, it can a this energy is not continuous. So, they can oscillate only with discrete energy, discrete energy and that energy E is n h nu, n equal to 1 2 3 etcetera integer.

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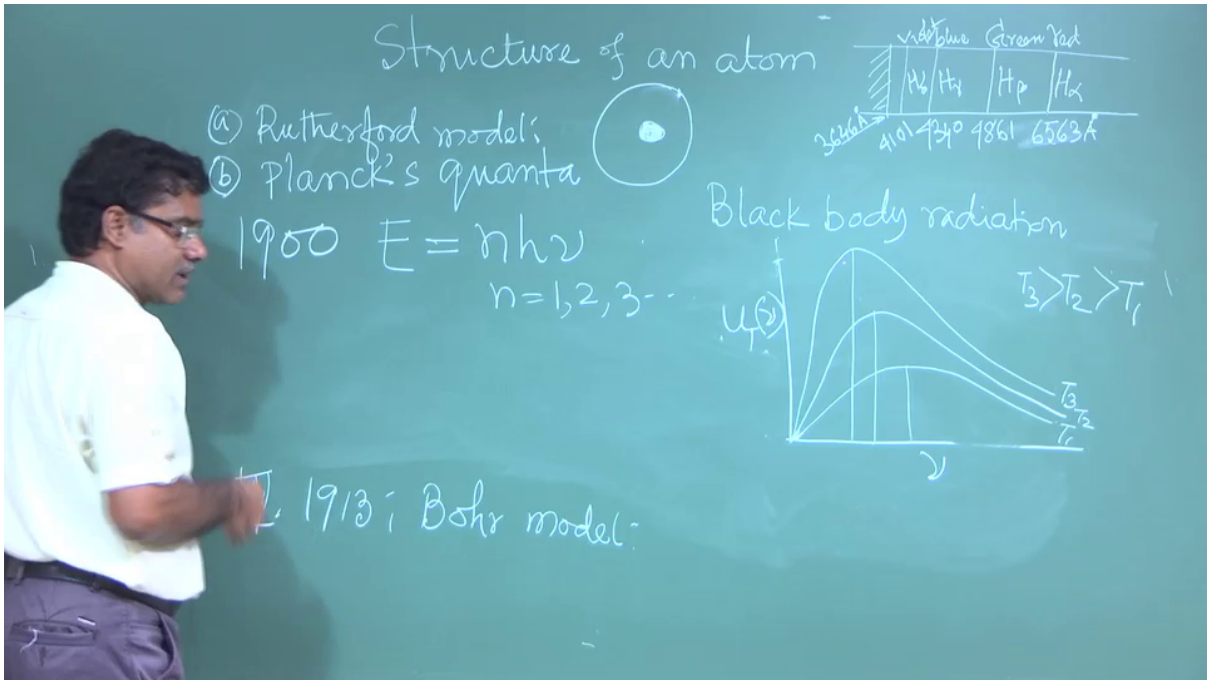

So, oscillators with which emit radiation, the oscillator oscillates with some energy that is H nu 2 H nu 3 H nu for then 2 H nu one can think H nu by 2, so frequency will be half. So, that was the postulates. And first postulates about the discreteness of energy or discreteness of our which was not conventional concept which is not classical concept because there is no reason why it will oscillate with some particular energy why it will not oscillates with all energy. So, as it is, this classical concept continuity continuous value is permitted either it can be energy it can be velocity it can be angular momentum.

So, he introduced first time that about against the classical concept. So, that is the birth. So, that is why 1900 basically one 1900, one is that year is taken has a birth year of quantum mechanics quantum concept. So, that that energy is not continuous energies quantize. So, this concept of quanta discreteness that concept was taken by Bohr. So, that is a Planck's quanta quantization of energy of any physical parameter. So, that concept was taken.

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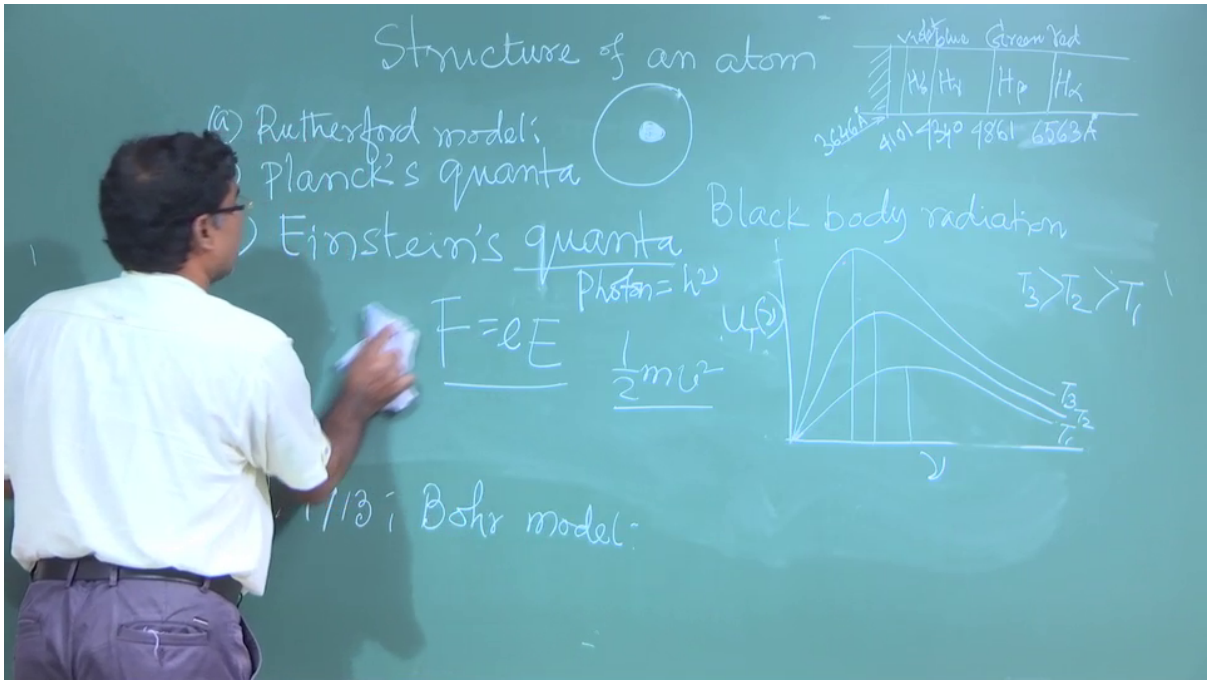

And third concept was taken that Einstein's photon or quantization of Einstein's quanta, Einstein's quanta. So, Einstein's quanta means to explain the photoelectric effect, so that was not possible to explain from the classical concept because when light is falling on a metal surface and it emits electron and the kinetic energy of the electron it was expected that this kinetic energy of the electron should increase when the intensity, when the intensity of the of the light is increased, but it was not observed intensity was increased, but energy of the ejected electron from the metal surface kinetic energy it was not increased.

So, why it should increase energy? Because intensities higher means this you see this electric component of light electric component of light right you know these light has 2 component electric and magnetic component. So, this electric component of lights is amplitude increase, its intensity also increase. So, when its amplitude increase of force, force on the electron that is e E force. So, force will increase on the electron, which electron? Electron on of metal surface, so it is the when force active on this electron so, that ejected electrons is kinetic energy should increase. So, whenever light intensity is increase E increase. So, kinetic energy of the electron emitted or ejected electron should increase, but experimental it is found not it is not the case. So, rather it depends on this kinetic energy depends on the wave wavelength of light or frequencies of light and then Einstein considered that this light again it is basically quantized.

So, this quanta is call photon, quanta is call photon photo and it is energy is basically H nu H nu it is quantized density category of that electronic depends on the frequency. So, it is not the intensity, it is this photoelectric effect that it kinetic energy of that electron it depends on the frequency of the light. So, to explain this photoelectric effect Einstein cons considered that quantization of light and that quantized photon and that differences between the Planck's and Einstein it is quanta Planck's actually considered the quantization of the oscillator and this it radiates the radiation a light or whatever. So, that is it will be it will have the same frequencies of the oscillator.

So, Bohr actually he combined this 3 concept, he combined this 3 concept and give a get 3 postulates gave 3 postulates one is first postulates, first postulates is basically the electron will rotate, electron will rotate or revolve only in some, only some definite orbit only some definite orbit, which orbit? The angular momentum of that orbit of the electron in that orbit that will be quantized. So, that has to be L equal to n, h cross is basically h by 2 pi h cross, n equal to 1 2 3 4. So, those orbits are permitted orbits are quantized those orbits are permitted that is angular momentum has to be equal to n h cross.

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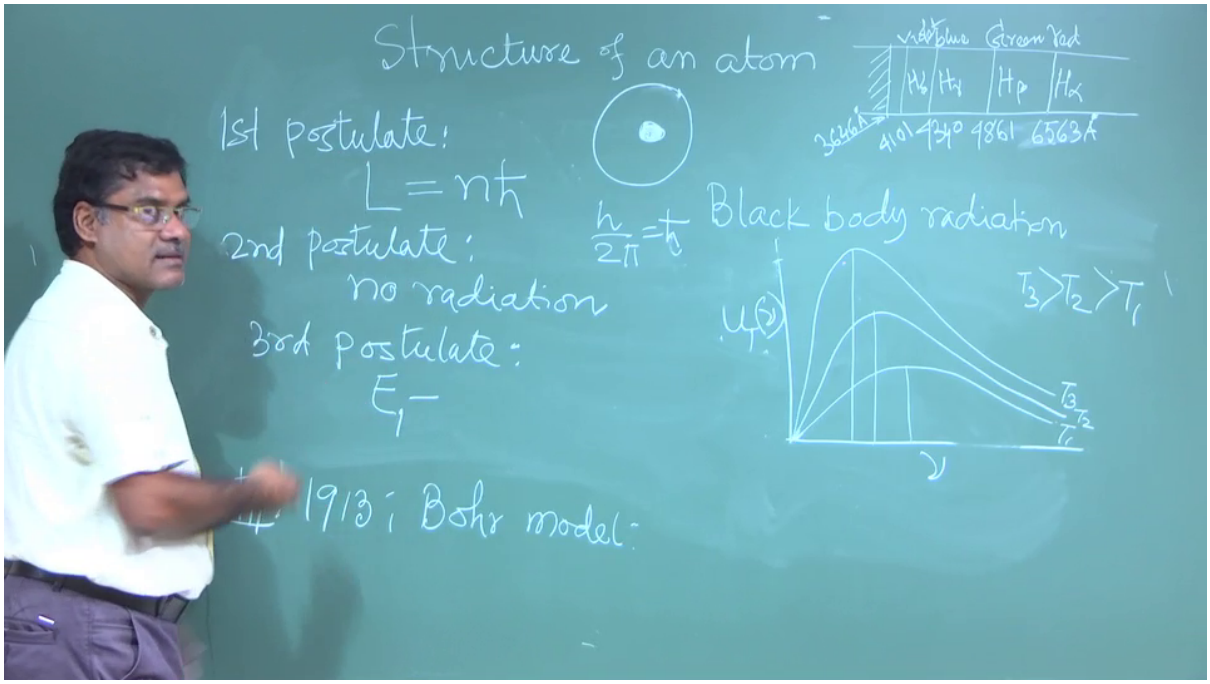

So, second postulates was, second postulates was when it will rotate in the definite orbit which follows this quantization, it will not emit any radiation, it will not emit and

radiation. So, no radiation, no radiation when it is revolving in the particular orbit definite orbit which comes from the first postulate and third postulate was third postulates was, when electron will jump from one orbit to the other orbit. So, then the energy difference between these 2 orbit that will come as a radiation that will come as a radiation and that. So, basically if it jump from one energy one orbit it has energy and the second orbits, let me write E 2 minus E 1. So, then it will emit radiation and that radiation is the energy will be H nu.

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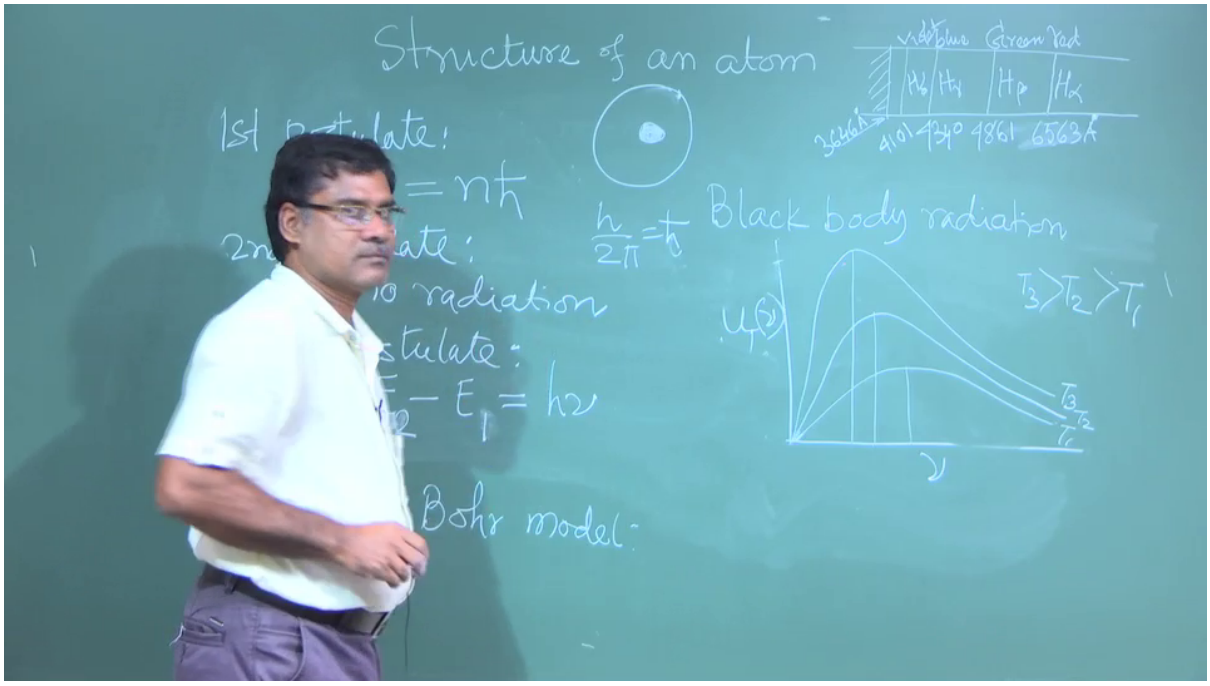

So, radiation only possible when it jumps it from one energy level to the other energy level. So, that was the 3 postulates. And we will see that consider when this 3 postulates will get formula expression of energy which is able to explain this hydrogen spectra.

So, I will stop here and then I will continue next class.

Thank you.