Atomic and Molecular Physics
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Lecture - 06
Structure of an atom

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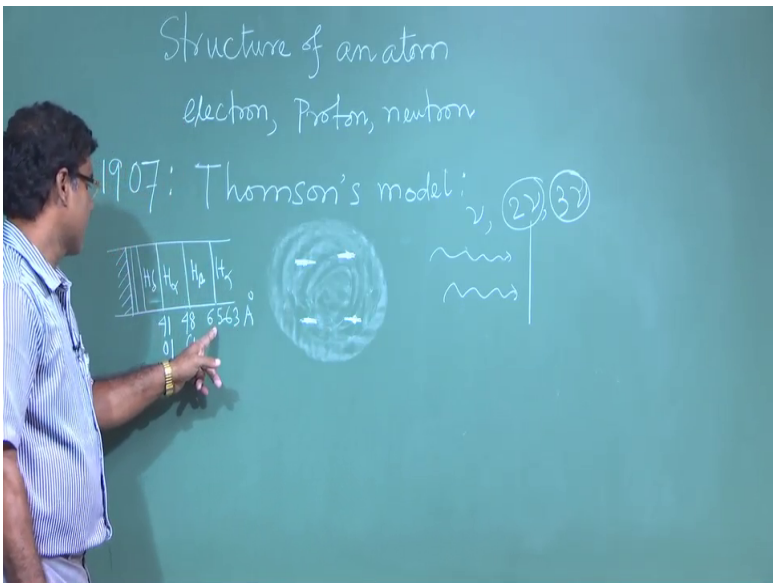

So, we will study structure of an atom; so already we know that this atom contains electron proton and neutron, but people started to think about the structure of atom. So, this first model was given by J. J Thomson in 1900; I think 7; Thomson's model for atomic structure.

So, what was that model what he during this time what was known? During this time, it was known that is atom contain negative charge electron and it has positive charge. So, this atom is made of negative charge; that is electron and positive charge, positive charge see when it is that positive; positive charge is proton that was not known.

So, Thomson's model is basically this; he considered that this positive charge is distributed throughout the atom. So, whatever the size of the atom that positive charge that is; this positive charge is distributed over this, over this size of the atom. So, and electrons are embedded negative charge and this is positive charge and negative charges are embedded at a particular definite position in the positive charge. And this negative charge; this electrons are not at rest; they are dynamic. So, they oscillate with the respect to their; that definite position.

So, that was the model model of Thomson about the structure of the atom. So, as we have seen that atomic spectra; that spectra whatever it was clear that origin of these lights spectra, that is basically substance; that means, atoms. So, from atoms; this light are coming, so that was known during the time that atoms is the source for this light. So here is 2 x because this model has to explain the atomics spectra.

So, Thomson told that when this electric charge oscillate; it radiates, so that is also known from electrodynamics. It has gone; if any charge particle oscillates or any charge particle is accelerated or de-accelerated; so they emit radiation, they emit light. So, his argument was that; this electrons, this negative charge embedded into positive charge, but they are not at rest.

So, the oscillate because of this oscillation; light this atoms emits lights and that is the source of this atomic spectra so, but problem was that; it is true that when charged particle oscillate, so it emits radiation. But the frequency or wavelength of this radiation frequency of this radiation; will be equal to the frequency of this oscillation. So, in case of hydrogen; only 1 electrons are there; now 1 electron oscillating.

So, it should emit only 1 wavelength; 1 frequency. So, we should see only 1 spectra lines, but hydrogen have more than 1 spectra lines, it can be more than 1 spectra lines because when 1 oscillator oscillate; so its frequency generally it can if it is nu. So, it can also emit this higher frequency; that would be 2 nu, 3 nu; high it is called higher harmonics nu, 2 nu, 3 nu. So, it is possible, but the intensity of radiation of higher frequency it will be very very very weak compared to the intensity of this frequency.

So, and in case of hydrogen spectra; we have seen this is whatever the spectral lines that I showed you. So, it is this kind of spectral lines; so h alpha line, h beta, h gamma, h delta. So, this wavelength was here as a 6, 5; I have to see that 6563 angstrom and this 1 4, 4 8, 6 1, 4 8, 6 1, 5 8, 6 1 angstrom; this 1 4, 0 4, 1 0, 1 4, 1 0, 1 angstrom; these are in angstrom. So, it is not that whatever the frequency, so wavelength you know; this relation between frequency and wavelength nu equal to c by lambda.

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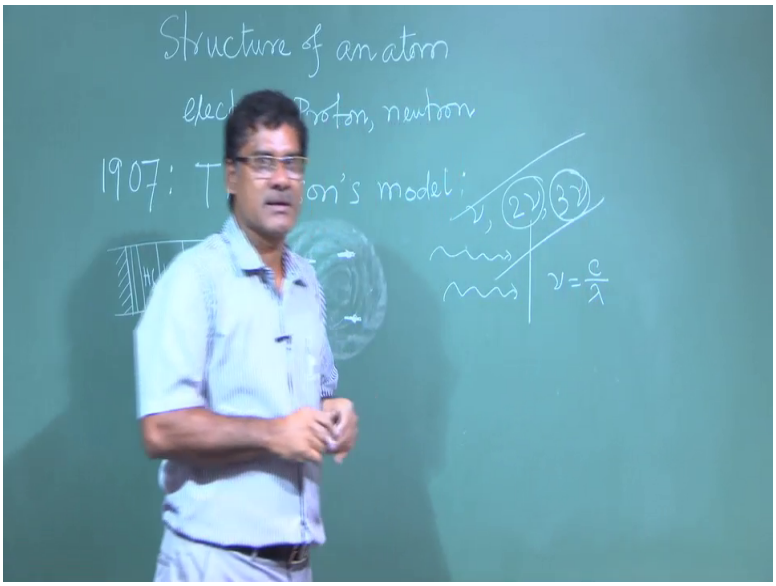

So, if we know lambda; so we can find out the frequency. So, c is constant; so it is not if you convert in terms of frequency. So, it is not this; it will not be it will not follow this relation it is not double or this half in terms of wavelength; probably, it can be just half of that one has to see.

So, it is not like that is no correlation among the spectral lines of hydrogen atom which will follow this type of relation. So, that was the biggest problem to accept the Thomson's model. So, then but atomic spectra that is the experimental fact, so people want to find out the origin of this spectrum; so, people are very eager to know the proper atomic structure of different substance.

So, of different substance; so atom but for different substance, this its mass and charge that will be different; that was also known for hydrogen, it was only 1 charge, 1 electron; so this the model was not accepted.

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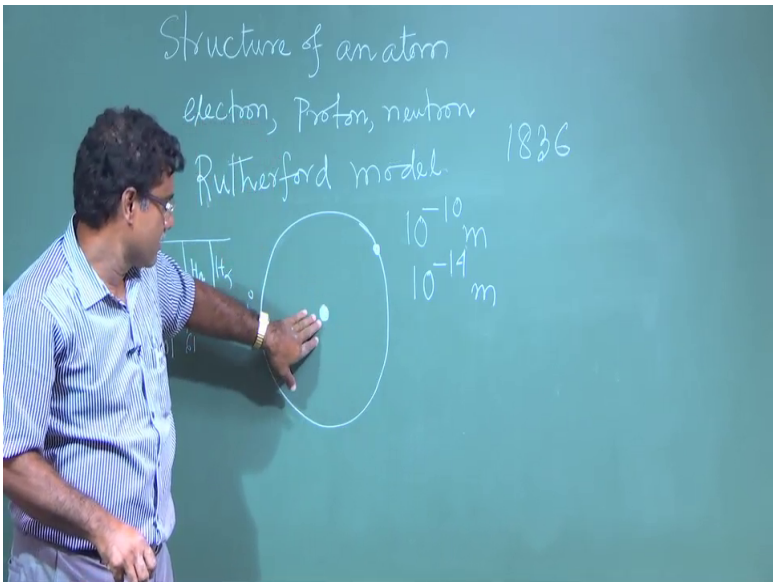

Then you know this 1911; this Rutherford came up with some model is called Rutherford model.

So, Rutherford is what was his model? So alpha particle; this that scattering experiment gold foil experimental experiment; so he did lot of experiments in his laboratory; scattering experiment and we have seen during the discovery of proton and he found that; this the proton that mass is basically concentrated in a very small region compared to the size of the atom.

So, from rigorous experiment; he found that this atomic size, if it is around 10 to the power minus 10 meter. So, this nuclear size of high proton is proton is concentrated that is the nucleus because whole mass; it was thought that whole mass, whatever observed in atom. So, that is because of the proton only and that whole mass is concentrated in a small area regions; that is 10 to the power 14 meter.

So, if you have this; this is the atomic size; so then this I think is smaller than this one; that will be the size of the nucleus higher proton, which contains proton. So, because proton is as I told this; it is almost 2000 or exactly probably is like this 1836 times heavier than electron. So, then he proposed that this basically; this whole positive charge is concentrated in a very small area, in a nucleus; very small area and electrons are basically moving revolving in a orbit.

Similar to our planet system; like this planets they rotate; revolves, planet revolves in a orbit and at the centre this sun is sitting. So, at the centre sun is sitting with nucleus in our case; here this nucleus protons positive charge are sitting and surrounding this electrons are rotating in a stationary orbit, so that was the model.

So, it is like our solar system; so, in solar system it is natural. So, and we know that from Kepler's law; so this their attraction between planet and this sun, this gravitational force and this centripetal force because of the rotation in a circle; in a orbit. So, this force; this rotational; this centripetal force, its direction is outwards and gravitational force; it is inwards. So, there they balance and thus they is the stable natural system; so in this case also one can think that these two type of force exist one; that is coulomb force.

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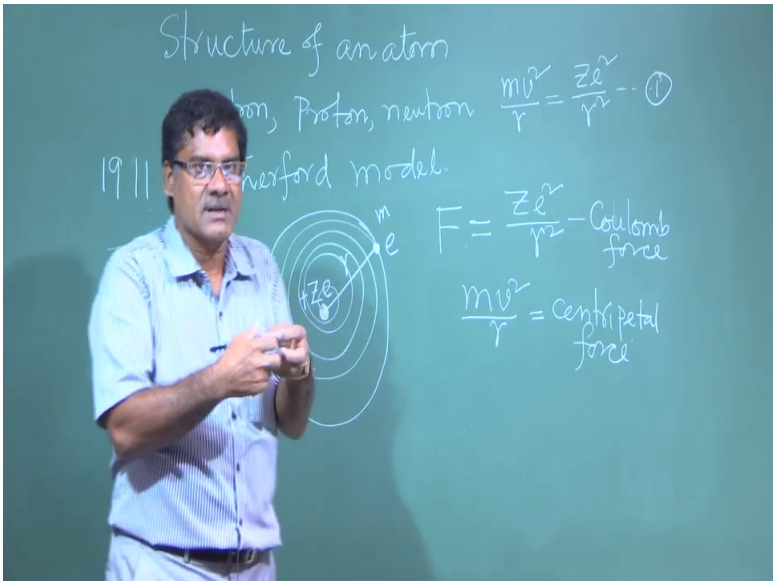

This is positive charge if we take it is Z e; so the Z is number of protons in nucleus. So, number of electrons also should be same Z, but if we consider just only 1 electron at hydrogen is having 1 electron.

So, for 1 electron system; so here you can be the simpler system one can think. So, in this case; if this is Z e plus Z e and this is e minus e electron charge. So, this distance; this radius of this orbit, so circular orbit was taken and if it is r. So, this coulomb force that will be Z e square by r; Z e square by r square q 1, q 2 by r square; so Z e into e Z e square by r square.

So, now this your centripetal force because it is rotating; what is that force? Centripetal force, you know this is mass is m; mass of the electron is m. So, that is that forces is m v square by r m v square by r m v square by r is the centripetal force is the centripetal force and this is coulomb force of course,. So, these two force should balance; so this m v square by r have to be m v square by r.

So one; we are getting m v square by r equal to Z e square Z e square by r square. So, now, this is fine but problem is difference between these graviton these solar system and this system. So, when charged particle is rotating; that means, there is acceleration, so whenever charged particle accelerate or decelerate; as I told according to the electrodynamics; so it emits radiation.

So, that was the concept that when electrons will revolve in the orbit. So, it will emit radiation; it will emit light and that is the origin of this atomic spectra. So, but now problem about the stability of the atoms; because when it is revolving and emitting radiation, so it will lose energy; its velocity will decrease and then it will follow spiral path.

And finally, fall into the nucleus; so then positive charge and negative charge both are in nucleus but they cannot exist like this in same place; positive charge and negative charge, you cannot keep them separate. So, atom will destroy; so, structures of atom will not sustain. So, this is the stability problem of the atoms, so it was not also accepted model for the structure of atom.

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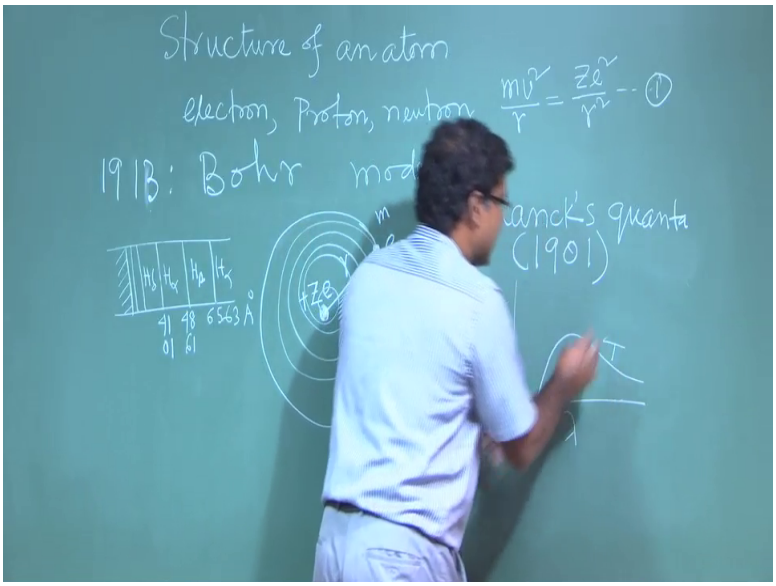

Then in 1913; Bohr came up with unconventional idea, so that is called Bohr model. So, what is that? So, he accept this model; Rutherford model. So, Bohr was the student of this Rutherford, basically Bohr was working in Rutherford's laboratory. So, this I think yes; so Bohr accept this Rutherford model means it is this; it is similar model of this solar system. So, Bohr except that one, but he incorporate some other idea, so this what was that I think this.

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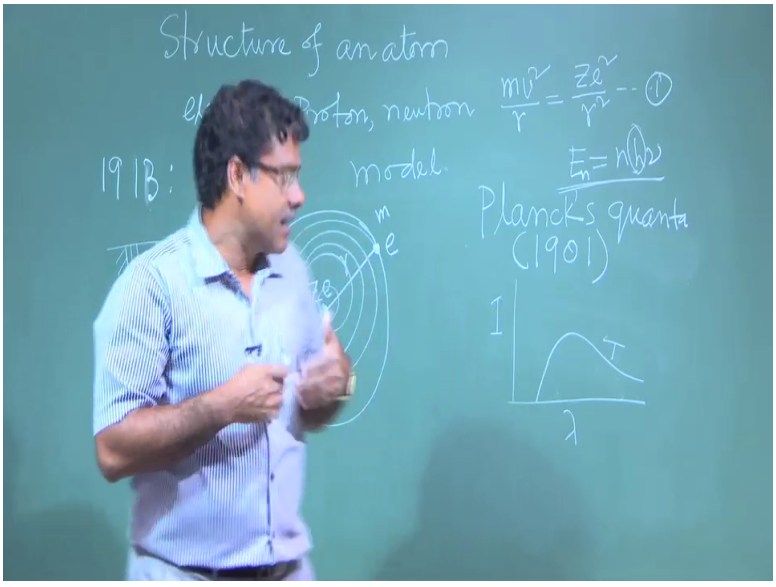

You know Planck's quanta? So that was in 1900; so that was discovered in 1901; what is that Planck's quanta? So, to explain the black body radiation; it is lot of study, black body radiation; you know this black body radiation is basically, if we have a hollow sphere or chamber and if you heat it; if you keep fit at a particular temperature.

So, it emits radiation of all wavelength; it has all wavelength but that the radiation intensity; intensity versus this, intensity versus this, intensity versus this I think wavelength. So, it has a particular distribution and this depends on temperature for distribution are this more or less similar.

So, that to explain that one; there was different different model to explain this black body radiation, but Planck's first; he was able to explain this distribution and for that he postulate Planck's postulates; he postulates that basically, he considered that the radiation is coming from the surface of the inner surface of the hollow sphere and there this materials are there.

So, basically they oscillate; there are oscillator, he considered a oscillator and they oscillate because of that oscillation that radiation comes and he quantised. So, this basically this now oscillator is oscillating, it can oscillate with any frequency, but he told Planck's told; Planck's postulated that no it cannot oscillate with any frequency; it can oscillate only with I think its energy has to be equal to n h nu.

So, oscillator oscillates it can oscillate only with those frequency when its energy will be quantised. So, this is the first introduction of quantum quantization of quantization of anything, so you see this it is whatever classically we have seen. So bus is moving with some velocity it has some energy; so now that is true it? Can it? Can move with any velocity depends on the power of this engine, but if I tell you that no, it cannot move with any velocity; it can move only with some certain velocity discrete velocity.

So, that is basically quantization; so that was very easy, it was not very easy to tell this words because in classical world all of us are familiar with this continuous motion, continuous energy, everything is continuous. So, discreteness that is this Planck's first; he introduced this discreteness restriction. So, that was the that energy of the oscillator; it is only quantized or its frequency is only quantized.

So, this h is Planck's constant of course, that is is known to you; now it is known to you. So, that concept; this quantization concept came first introduced by Planck's and that was in 1901 and then next one was the I think photoelectric effect by Einstein.

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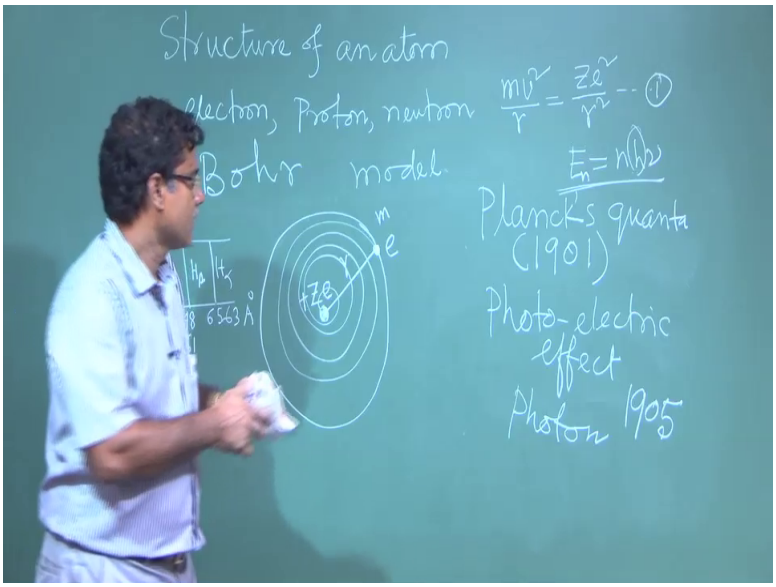

So, earlier this our normal concept is that; so when light is falling on some metal; have the free electron. So, when light falls on that then this light is absorbed by the electron and it is ejected from the metal surface, then if you measure the energy of this electron; this kinetic energy.

So, that has to be related with the energy of this light falls on the metal surface. So, energy of light energy of radiation energy of anything means; if light is brighter and brighter, if intensity is higher and higher, then more electrons should come out from the metal surface. Because we are giving more energy to the system; to the metal, so more electron should come out; so that was the normal concept.

But that experiment; what about this photoelectric effect? That experiment whatever. So, it was not happening and it is found that it depends on how many electrons will come out from the surface? That depends not on the intensity of light, it depends on the wavelength of the light frequency of the light.

So, that was not understood; so Einstein that he again; he introduced the concept of quanta quantization. He told that no; light is also quantized that quanta of light is called photon

quanta of light is called photon. So, basically this Planck's and this Einstein; this concept here this basically oscillator is quantized oscillator oscillating.

So, it cannot oscillate with any frequency; so it can oscillate with only some quantized frequency. So, whenever it is oscillating; whatever its frequency, it will emit light of that frequency. So, thus this we are getting light of different frequency, but Einstein suggested that light is itself is quantized.

So, whatever ray we are telling light ray; it is passing going actually this ray, this is this ray is ray of photons; like cathode, ray cathode ray is nothing, but the ray of electrons particles. So, ray of light is nothing, but the ray of photons. So, photons is like a particle in cathode ray electron is a particle; similar in light ray photons is a particle.

So, that concept was introduced by Einstein; it is again quantization. So, if that was in I think 1905 and then in 1911; so Rutherford thought of this type of model. So, Bohr based on this three concept, this existing concept, he gave model; he took bold step that was really bold step and he gave the model and basically 3 postulates of Bohr, what is that? So, I think; I will stop here because it will take time; I will continue next class.

Thank you.