Atomic and Molecular Physics
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Lecture - 05
Experimental observations and theoretical development in discovery of constituents of an atom (Contd.)

So, will continue our study about the constituent of an atom, so we have seen what we have learnt.

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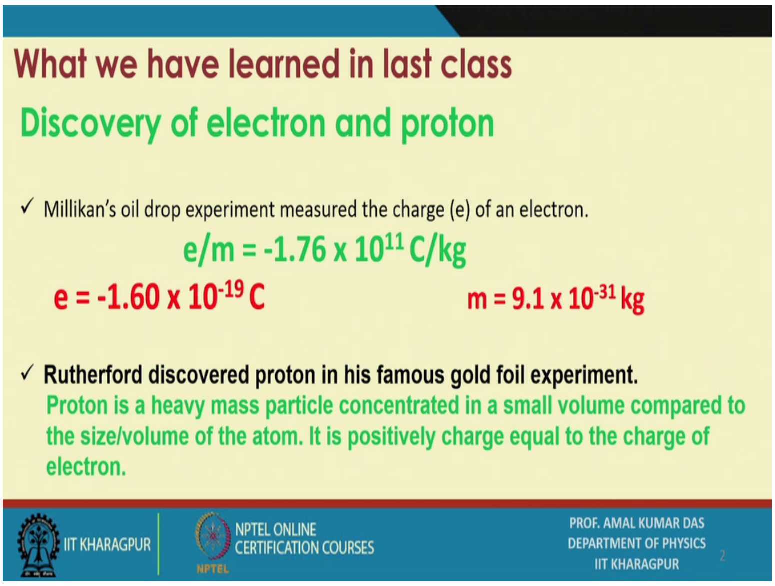

So, we have seen about the discovery of electron and proton and this charge and mass of electron from JJ Thomson's experiment as well as Millikan's oil drop experiment, that we have seen the charge of electron is 1.6 negative of course, into 10 to the power minus 19 coulomb and mass is 9.1 into 10 to the power minus thirty 1 k g kilogram. So, that is that was about the electron and then we have seen the discovery of proton by Rutherford from is famous gold foil experiment.

So, basically proton is a heavy mass particle, concentrate in a small volume compared to the size of volume of the atom. So, it is positively charge equal to the charge of electron. So, it has positive charge equal to the electron charge, but it is very heavier than the electron and all mass is concentrated in a small area region in the atom. So, size of the atom and size of this has basically nucleus this I think it is one 10000th of the size of the atom. So, I think the size of the atom if it is around 10 to the minus 10 meter, then the size of the nucleus where proton is concentrated, this around 10 to the power minus 14 meter. So, this difference is 10 to the 4 order of magnitude.

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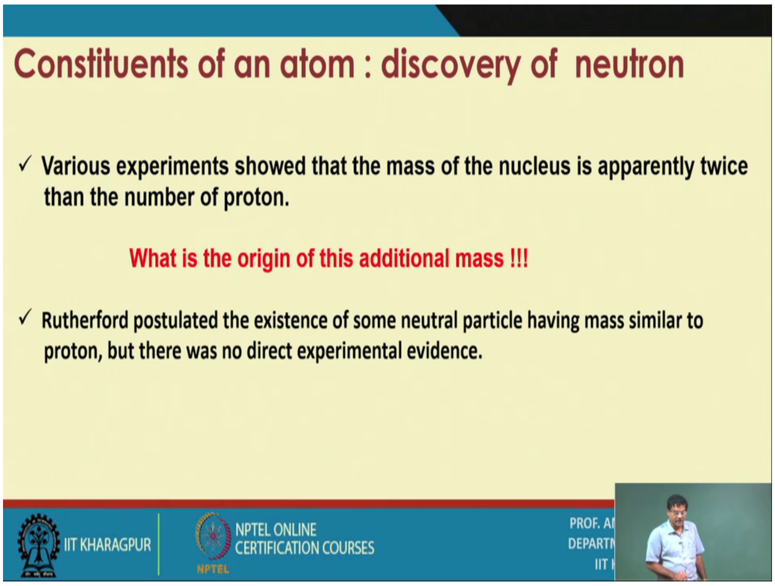

So, now will see the discovery of neutron, so various experiment showed that the mass of nucleus is apparently twice then the number of proton in nucleus. So, what is the origin of these additional mass that was the question and Rutherford postulated the existence of some neutral particle having mass similar to the proton, but there was no direct experimental evidence of these postulates.

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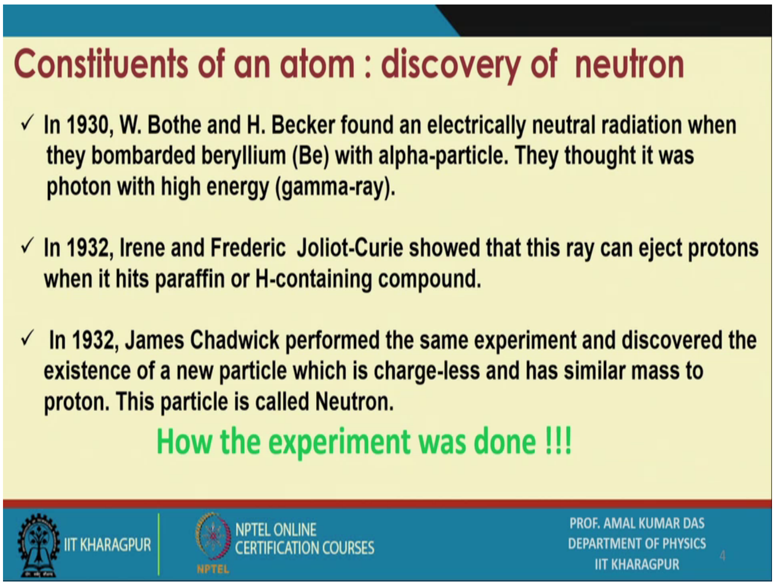

So, then in 1930 W. Bothe and H. Becker they found an electrically neutral radiation, when they bombarded beryllium plate or window with alpha particle, so that means this they took a source of alpha particle, say this is the source of alpha particle.

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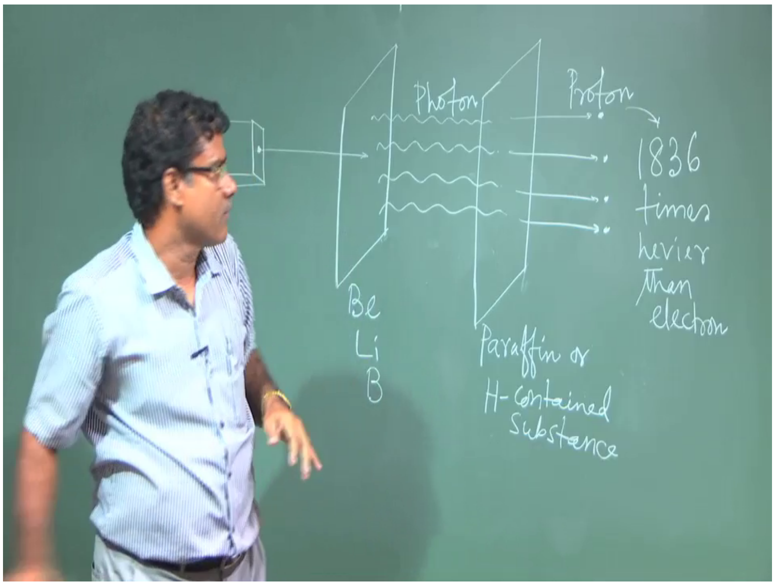

So, alpha particle is emitted from the source and they put a file and this alpha particle bombarded this file. So, this they took the beryllium file they took also this lithium file, boron file.

So, these basically file of light element. So, this when it alpha particle bombarded on this then Bothe and Becker they found that an electrically neutral radiation emitted from this file. So, that of and they thought that this neutral radiation is nothing but a photon with high energy, so they thought they are photon. So, this photon this light is neutral. So, it is neutral it was confirmed and they thought it is photon, but will see actually it is not photon. So, then in 1932 this Irene and Frederic Joliet curie they showed that if this radiation hits another screen or another film, it is paraffin or this hydrogen contained any others substance contained substance ok.

So, then they found Irene and curie they found that, from here some particles are emitted from there and this particles are basically proton. So, that was the observation of Irene and curie.

So, now question then in that, so say in 1932 Irene and this curie they did experiment, they extended the experiment of the of the Bothe and Becker and they also they did not think about a this radiation, which is coming out from the barium beryllium; they thought this is photon, now it is now this photon again bombard this paraffin's and then from paraffin this protons are coming out.

So, now question was arises that there are lot of discussion on this experiment and question was arises that if it is photons is very light right, it is mass less and now it hits this file of paraffin and from there this particles are coming out protons are coming out, which mass is very heavy, it is I think 1836 times heavier than the proton, is 1836 times heavier than electron. So, this how photon can eject, this heavier particle from paraffin it is impossible.

So, then in 1932 itself with James Chadwick he perform the experiment the same experiment, taking different this target besides this paraffin some other target also he used and he analyse the change of energies of this target and he found that this is not a photon, it is neutral but it is particle.

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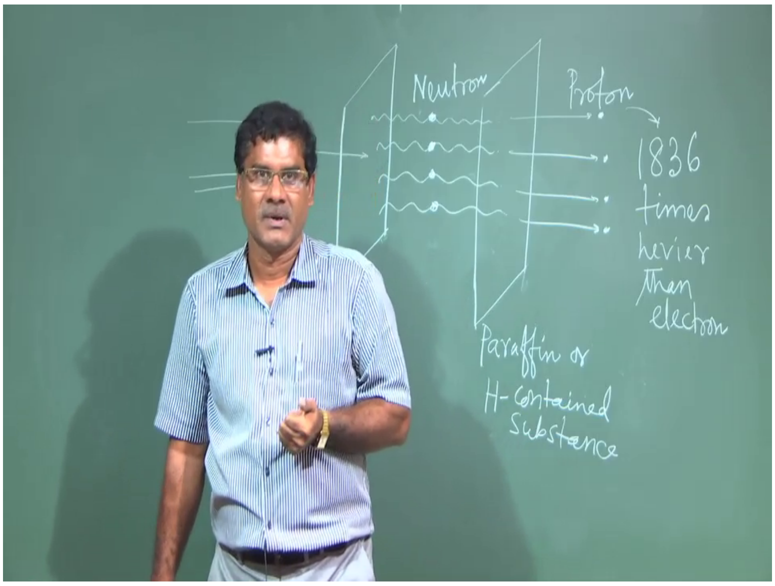

But it is particle, so this particle we analyse this particle and we found this particle as a neutral and it is mass is similar to the mass of proton. So, these are is a new particle and he called he get the name of this particle is neutron. So, thus another particle another constituent of atom is discovered that is neutron ok.

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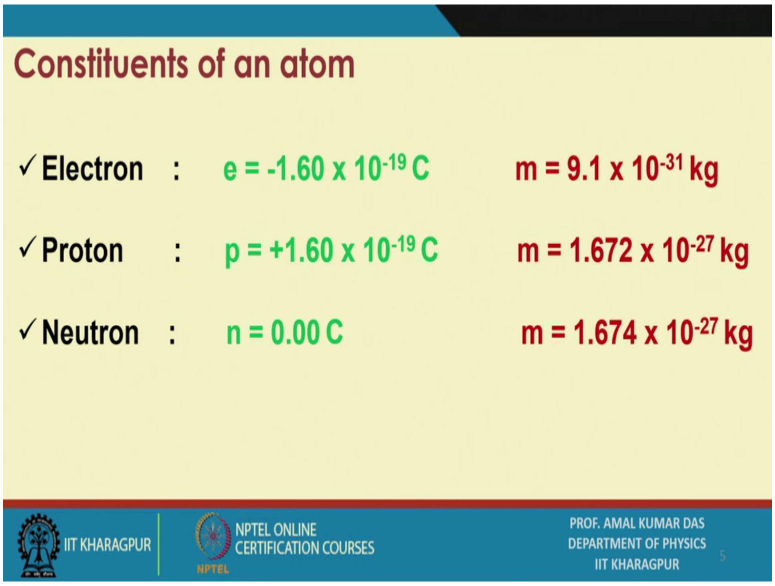

So, now we know this overall this constituent of an atom that is basically electron, proton and neutron. So, you can see how long time was taken to this quark this constituents of an atom right, see it is up to 1930 it was known about the about the neutron. So, it is nice now we know or it is clear to us that constituent in atom electrons are there protons are there and neutrons are there and protons and neutrons they are in nucleus they are heavier particle and they are concentrated in a very small region in the atom that is called nucleus. So, we have nucleus and this atom where electrons are there anyway. So, that was about the constituent of atoms.

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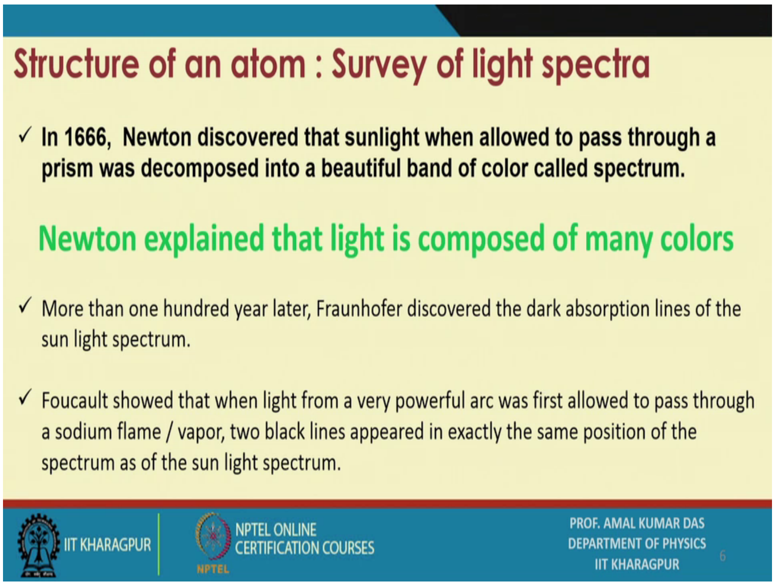

Now, we will see the historical background of structure of an atom, means this how these particles are arranged in a atom. So, that also long history, it took long time to understand as this time taken for the discovery of the constituents of an atom. So, here just for determining the structure of an atom, this light spectra that was very helpful means without that analysis of light spectra or without understanding the light spectra it was not possible to understand the structure of the atom right. So, structure of the atom means, how the constituents are arranged in the in the atom. So, as I told this light spectra have contribution major contribution to or only contribution to understand the structure of atoms.

So, let us survey the light spectra. So, it is also long history as I mentioned that is in 1666 Newton discovered that, sun light when allowed to pass through prism was decomposed into a beautiful band of colour called spectrum. So, when sunlight was allowed to pass through a prism, then spectrum that colour spectrum or colour band was observed; now before Newton basically that was observed whenever the sunlight passes through the through a clear crystal and then this colour band was observed, but that was explained that it was thought that this colour band was generated by the crystal, but first Newton he explained that this light itself is composed of many colours, it is this colour is not generated by the prism or crystal. So, that that was the right explanation basically later on we found.

Now, we know so but that time Newton first he predicts, he mentioned that light is composed of many colours. So, after that more than a 100 years later Fraunhofer discovered the dark absorption lines of the sun light spectrum, means sun light earlier that earlier this spectroscopy spectrometer there is it was strong measurement this science was this field was very strong in spectroscopy. So, without understanding, but analysing the different kind of spectrum that was going on and so another observation by of by Fraunhofer; what was that observation? This you have spectra of sunlight, so there were some spectral lines but some lines are missing or block lines some lines are missing, very few but some lines are missing; so that is called dark absorption lines. So, why it happens in spectra bright lines are there that is fine.

Now, some lines are missing some lines are absorb so why it happens? So, that next Foucault showed that when light from a source, basically from a powerful arc means this if you take 2 electrodes, so positive and negative power is given. So, it will take them very close year gap will be there means there will be high resistance and then this spark you have seen spark sparking right we tell sparking.

So, light comes out ok so that is an arc. So, from this arc it is basically will get very bright light from this arc. So, Foucault he when he passes this very bright light through the sodium vapour or sodium gas flame. So, then after that he analyse the spectra and he found that the 2 lines are missing that is called d lines probably, you know or if you do not know I will teach it later on. So, sodium light is called d lines d 1 d 2 lines. So, this 2 lines very bright line, very famous lines from sodium source, so these 2 lines are missing d lines are missing. So, original light from arc, so if you just directly see the spectra they what about the lines are there ok.

Now, if you before taking spectra if you pass through the sodium vapour, then it is seen that the 2 lines are missing, so 2 black lines are observed. So, why it happens? So, that was the discussion big discussion. So, what is the origin of this black lines, so this immediately Kirchhoff he came up with theory that sun is surrounded by layers of gas acting as absorbing screen because, as observation was that this sunlight spectra have the absorption lines and Foucault that he showed that when light passing through a medium, passing through gas or vapour, say sodium in this case then this corresponding lines are missing, d 1 d 2 which is the basically source of comes from the source of sodium that 2 lines are missing. So, we can say that this light from arc. So, it was having this all spectra lines.

Now, when passing through the sodium vapour, so that 2 lines are absorbed by the sodium. So, it has so matter has absorbing power it has a emitting power, so also it has absorbing power. So, that was assumed by the Kirchhoff and he immediately came up with the theory that, so from sun whatever light is coming it has absorption lines means some gases are they are surrounding the sun and the gas absorb that is corresponding lines and that is the origin of the absorbing black lines. So, that way things was developed and then also Kirchhoff gave experimental proof that was in 1859.

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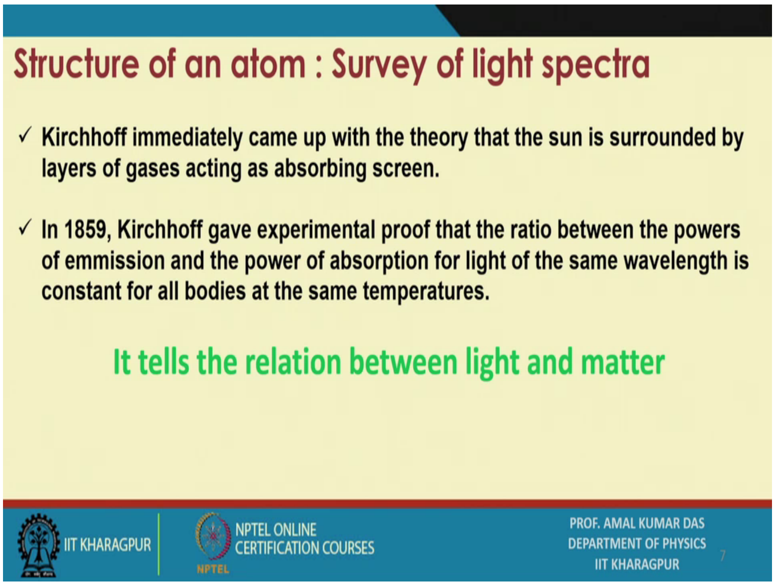

The ratio between power of emission and the power of absorption for light of the same wavelength is constant for all bodies at the same temperature, means if you take any bodies if you keep them at same temperature ok.

So, now for a particular light for a particular wavelength, the absorbing power of any substance out of them, the ratio of absorbing power sorry ratio, of the emission power and absorption power that is always constant. So, from here you can see that absorption or emission of light, so it depends on the substance and it depends on the temperature. So and also 1 can tell that that for a particular substance if it emission power is high for a particular wavelength, so it is absorption power will also be high for the same wavelength ok.

So, this type of corollary you can draw from this experimental result. So, basically it tells about the relation between the light and matter they are related.

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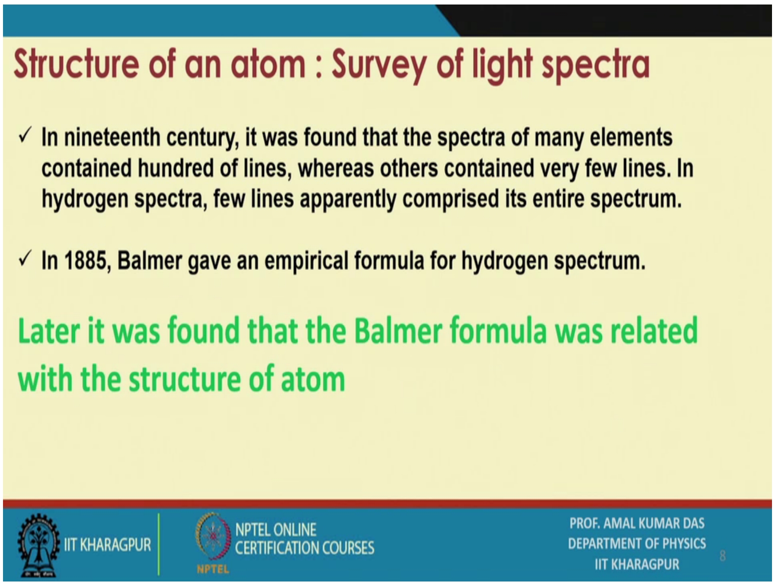

So, next in 19th century, it was found that the spectra of many elements contained 100 of lines many lines, whereas there are some elements which have which contain only very few lines. So, in the hydrogen spectra few lines apparently compromised it is entire spectrum. So, for hydrogen this it is spectrum contain very few lines, but there are some and other elements also there which have few elements, but there are many elements which have which contain this spectrum of that elements contain many lines ok.

So, whether you see spectra is basically is light wavelength it depends on the wavelength of light. So, basically it is light and it is related with the elements substance. So, this spectra basically substance dependent right matter dependent, So matter contains that atom right matter is made of atom right and now the light spectral light is basically it is related with the matter related with the substance; that means, is related with the atoms.

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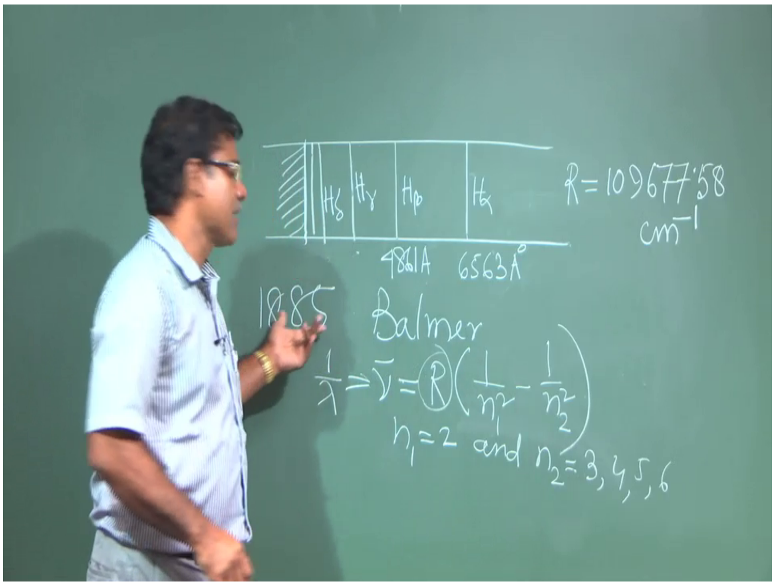

So, hydrogen spectra was known was known in 19th century and this spectrum was like this and so this all is then continuous basically. So tells h alpha line h beta line h gamma line and I think this h delta line. So, these are very prominent lines it is wavelength I can write, I thinks this is 6 5 6 3 angstrom, so this is having 4 8 6 1 angstrom. So, this similar way this it has this wavelength also measured and now but it was unknown that how these lines are coming. So, it is coming from hydrogen gas. So, that time it was not known probably about the concept of atom anyway.

So, but it was difficult to understand what is the source of these lines, but in 1885 I think Ballmer gave an empirical formula, that formula was like this nu bar equal to r 1 by n 1 square minus n 2 square. So, if you take n 1 equal to 2 and n 2 equal to 3 4 5 6 etcetera, then for a particular value of this r and that value to fit with this value these to get this wavelength ok.

This nu bar is basically 1 by lambda is called wave number, so it was found that it was found that this if r is 1 0, I think I have to exactly yeah 109677.58 centimetre inverse; if this value is taken then and n 1 equal to 2 and if you take n 2 equal to 3. So, exactly this wavelength is these lines we get, then n equal to 4 this n equal to 5 this 6 is etcetera and for n equal to infinity you get this lines you really get, so that was the empirical formula there is no basis because in 1885, nothing was known about the atom right.

Even I think so discovery of electron proton, neutron this only after in 1897 electron 1800, 1911 this proton and 1932 this neutron. So, anyway this was nice empirical formula. So, it can fit it can gives this data, so but this r has to be this constant. So, this way later it has found that of course, Ballmer formula was related with the structure of atom that we learned. So, I will stop here I will continue in next class.

Thank you.