Atomic and Molecular Physics

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Lecture - 14
Structure of an atom

So, we have seen Bohr sommerfeld model in last class.

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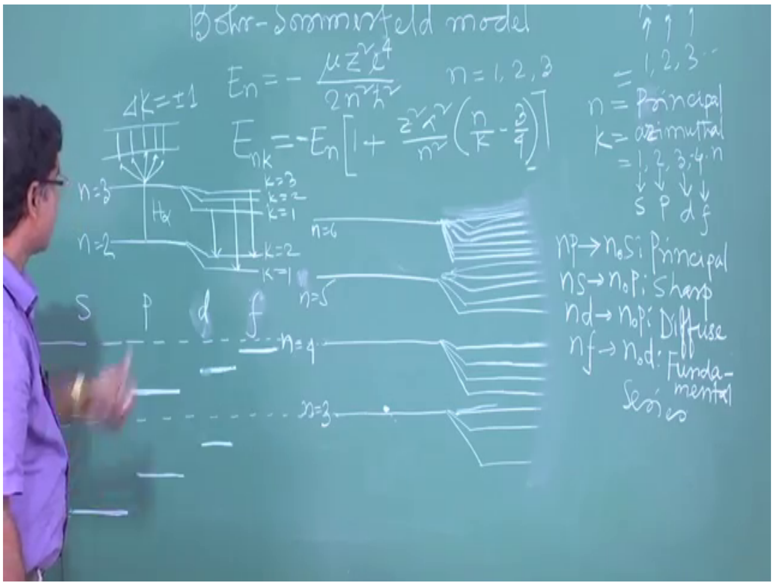

And we have seen that from Bohr model energy expression is mu Z square e to the power 4 by 2 n square h whole square. So, here this n is principle quantum number is quantum number 1 2 3 4 and this was successful to explain the hydrogen atomic spectra specially this series Limen series Bohr series then (Refer Time: 01:26) series (Refer Time: 01:26) series right.

So, this in each series the separation between the spectral lines is decreased and it tends to continuum or the tends to the limit value of the spectral lines. After that it is continuous basically and then. So, that this quantum number is one and this quantization of one parameter that was angular momentum, and then sommerfeld introduced the another quantum number; that is, Azimuthal Quantum Number and using the special theory of relativity special theory of relativity this energy if velocity of the particle is high close to the light velocity then one has to consider one has to consider the special theory of relativity not it is then relativistic case not non-relativistic anymore

So, this energy from Bohr sommerfeld model or from extension or Bohr model by sommerfeld. So, that that En this minus we introduced here just for convenience. 1 plus z square alpha square by n square then it was n by k minus 3 by 4. So now, energy depends on 2 quantum condition 2 quantum condition and that gives 2 quantum number. So, n it is a principal quantum number, n principle quantum number and k is angular quantum number Azimuthal Quantum Number.

So, this k value it takes n value it takes 1 2 3 4 and k value for a particular n, I let us take 1 2 3 up to n. So, so generally this this this principle quantum number. So, 1it is shell and it gives named that we use name this k shell, l shell, m shell, n shell etcetera. And now for each shell is now subdivided into sub cell or this is also called orbit.

So, each orbit is sub divided into orbitals. So, this name is given for k equal to one is given s orbitals, p orbitals, s p b then 4 is basically f. So, these are the name we used for orbits and orbitals and I have shown you that that this people are in search of more quantization, because the spectral lines hydrogen spectra say whatever from Bohr theory whatever we get that all line say H alpha, H beta, H gamma, but it is not 1 line it is more than 1 line it is composed of more than 1 lines. And so, so of people speculated that. So, we need more quantization.

So, there will be more energy levels and corresponding from transition we will get more spectral lines. So, here we have seen that if I draw this for hydrogen atom. So, h alpha. So, you know this n equal to n equal to 2 2 n equal to 3. So, that is the transition is in (Refer Time: 06:40) series.

So now it was based on this now if we use this energy. So, this each energy level will be splitted. So, this n equal to 2. So, k equal to 1 and 2. So, then it will be 2 lines and I describe that energy generally it is become it is decrease means become more negative. So, this is on k equal to 1 and this is on k equal to 2. Similarly, here it is 3 lines 3 energy levels. So, k equal to 1, k equal to 2 and k equal to 3 right.

And this using this transition rule del k selection rule del k equal to plus minus ,1 that I have I have shown you that that this transition is possible and then 2 2 1 is possible and 3 2 2 possible. So, actually we will get 3 lines, but experimentally it is found experimentally it is it is seen that this spectral line this is it is composed of basically 5 lines it is composed of 5 lines is composed of 5 lines.

So, still that Bohr sommerfeld theory still it is not able to explain this experimental result this all fine structure. So, it is not able to explain the fine structure and another aspect, I discussed that this alkali atom, alkali atom I think I discussed earlier; that alkali atom it is spectra is similar to the hydrogen spectra why is it similar that I have explained you explained you that in outermost cell it is one conduction electron and other electron is basically still the nucleus and so one can think that this it is like hydrogen atom of one electron, outermost electron and the resultant this nuclear positive charge is (Refer Time: 09:28) by the outer electrons. An effective positive charge it is close to 1 like hydrogen or it varies basically depending on the screening.

So, in case of alkali atom say let us take sodium. So, sodium has 11 electron. So, outermost electron is in n equal to 3. So, so for sodium if I for sodium if I draw this energy level n equal to 1 n equal to say n equal to 2 and n equal to 3 n equal to 3. I should show. So, if I take n equal to 3. So, n equal to 1 n equal to 2 n equal to 3. So, this this outermost electron is basically at here and these 2 are filled these 2 are filled for sodium 2 electron and then this is 8 electron at n 2 equal to 8 (Refer Time: 11:20). So, 10 electron. So, 11 is having 11 electron. So, outermost electron is this one and these 10 electron is cleaned it is cleaned the positive charge 11 positive charge. So, effectively it is.

So, this outer electron; we will see this positive charge is close to 1 plus 1 charge plus e charge. So, then it is it is similar to hydrogen atom, and then this energy for a hydrogen atom this energy expression can be used for sodium also where 1 has to replace Z it is not 1 it is generally people write Z minus sigma, Z equal to 1 can replace z by z minus sigma is called screening factor screening constant. So, Z minus sigma it is close to it is I think for sodium it is sigma H 7124 kind of things. So, it is it is not effectively shown it is around 2.4 kind of positive charge. So, anyway for that there will be shifting of the energy levels, but nature of the energy levels means their discreteness and their transition will not be affected.

So now this electron. So, there is a possibility to jump at higher levels higher levels n equal to 4, n equal to 5 then n equal to 6. So, this 2 is not effectively will not participate in transition. So, let me drop it let me drop it. So, these are just from Bohr model one can draw energy levels like this, but separation of energy level of course, it will be it will decrease, but here it is not I have drawn it is not in scale. So, this now this Bohr sommerfeld theory whatever the energy expression we have got. So, that also valid should valid for this alkali atom, because it is similar to hydrogen atom as I mentioned.

So, what will happen. So now, depending on k value this energy level will split as we have shown here. So, here you can see this this n equal to 3 it will be splitted into 3 energy level it will be splitted into 3 energy level. This is 1 and then, second one say this and say third one is say it is third one is sorry like this. So, that one will be k equal to 1, k equal to 2, k equal to 3. So, similarly this energy levels also will split. So, or 4 say like this similarly others also split. So, this one will be k equal to 4 3 2 1; 4 3 2 1. So, this as I told this k equal to. So, this in principle I can write this one is s s p d s p d f like this. So, if I just plot in slightly different way that. So, this is also this they will also split into this

So, one should one should 5 lines one should this one how many 6 lines 1 2 3 4 5. So, one has to. So, it cannot be higher than this this cannot be higher than this. So, it can be equal it can be equal. So, in between it has it should accommodate 6-line 6 energy levels. So, later data it is splitted. So, each one will be splitted into orbital s p d f g h. So, if I just if I plot just s level p level. D level. F level. F orbital s p d f. So, I think I should write with small letter d s.

Now, here for n equal to 3 there will be 3 there will be 3 orbitals s p d. So, energy of s if I plot here energy of s is here. So, I think you can see energy of s is here then for p it is half then for p it is half. Like this then for d. So, it will be like this. So, these 3 orbitals for basically n equal to n equal to 3 lines n equal to 3 lines if I just extend it. So, for n equal to 3. So, this 3 orbitals similarly for n equal to 4 I will get s p d f.

So, if I plot s p d f. So, s yeah and sometimes it is energy is penetrate also inside of this one. So, it is it is for s lines it is I think it is if I plot like this, then for p just above it for p it will be above it, then d it will be above it, and then f then I will get f. So, it is it is energy level is basically for n equal to 4 n equal to 4 similarly, you will get for n equal to 5 n equal to 6 one can draw if I do not draw more. So, this what we are seeing this this lines for n equal to 3 below and this n equal to 4.

So, here if I consider transition following the rules del k equal to plus minus 1. So, there are 4 series as I mentioned earlier one can experimentally see 4 series for alkali atom what are those 4 series it is principle series np to say n0s if this transition this transition gives the series is called principle series. And then ns to n0p it is this transition gives the series is called sharp series, and then nd to n0p. So, this transition give a it is it is principle series sharp series and this is called diffuse series diffuse series and another one n f to n 0 d transition between these

2 it is gives another series is called fundamental series, fundamental series. So, these are this 4 series are observe in in in alkali atom here for alkali atom one can see.

So, here we have considered sodium. So, and in this series are similar to the hydrogen atom series; means the separation between the spectral lines decreased and up and it goes towards the series limit whatever we have seen for Bohr series Limen series here also similar series we so now, this series here you see this p to s because this or s to p because this selection rule del k equal to plus minus 1. So, according to that this transition only allowed this transition are allowed. And so, this is the these all lines here are p p lines here all are d lines d energy levels here f energy levels. So, I should draw more to show series I should draw more here I think I can’t. So, I will write later on

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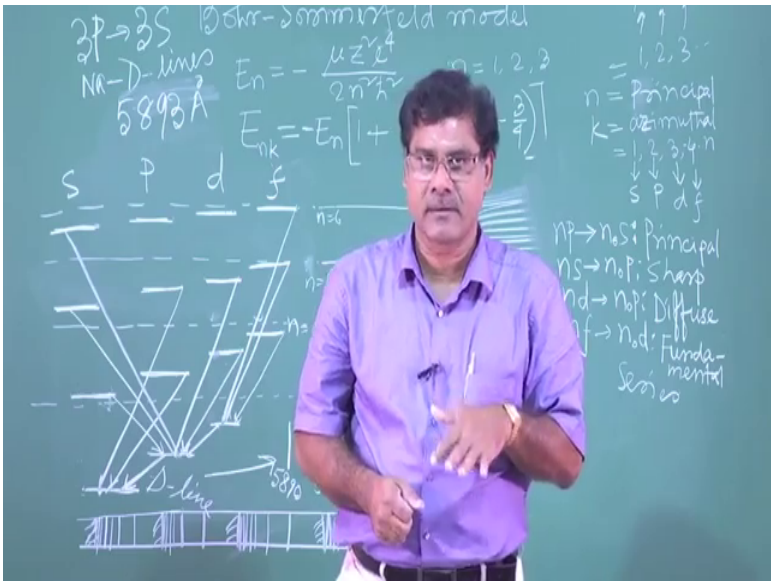

So now for this for this one n equal to 5, again we will get I think that and then this is f this is d we will get d and then we will get p, p and then we will get s, similarly n equal to 6 also. So, I do not need higher one. So, there is a there are 5, but here I have (Refer Time: 23:29) drawn 4 s p d f. So, here also f. So, n is higher. So, these are becoming negligible. So, difference from it is not divided from n equal to 6 energy level.

So, these are s p d f. So, to show the transition I need more line. So, that s what I have drawn. So now, you consider that it is you see it can be any n know and any n 0. So, n and n 0 it is not (Refer Time: 24:13) to be same it may be same it may be different, but main thing is that p to s p to s. So, this is the line p and this is the line.

So, n 0; that means, this target from different higher lines, higher energy levels. So, it will jump to the just lowest one. So, here you can see this is s line So, from this p to s. So, this transition is allowed this transition is allowed then this transition is allowed this transition is allowed. So, this transition all from all free levels there is (Refer Time: 25:02). So, it will. So, you see this is the energy difference this is the energy difference energy becoming higher wavelength will be smaller. So, it is becoming smaller, smaller, smaller and then it is goes to the wavelength limit. So, it will it will form a series it will form a series. So, if I just show here just if I show here this series. And so, here 3 lines I have drawn.

So, these lines wavelength are smaller and smaller. So, basically you will get series. So, it is let us see this limit as if like hydrogen series. So, this series is called principle series now then s to p s to p. So, this is the this is the lowest free level. So now, from s higher s it will jump. So, these are the s lines. So, from here this s lines to it will one can. So, this will be the one transition then this will be the another transition. So, this will be the transition. So, this way you will get transition and again similar series you will get basically it is and then series limit. So, this series limit series will be this sharp series similarly another series d to p. So, these this is the d lines d energy levels and this is the p lowest one lowest p is this one. So, I will get transition this I will get transition this I will get transition this etcetera right.

Again, this wavelength will decrease towards. So, I will get another series and then serial limit and then another from f to d. So, this is the f energy levels. So, to d. So, this is the lowest d. So, lowest one we have considered in 0. So, here n 0 is for all cases is 3 and n n are n are different. So, you will get transition this is allowed transition this is allowed transition this. So, you will get another series is called fundamental series here also similar you will get. So, it is similar to the series of hydrogen atom, and that is that is now that is the how this series are coming. So, it was not possible to explain from the Bohr expression energy expression, but from Bohr sommerfeld expression now we can explain the series. So, this is the in some extent this is the success of Bohr sommerfeld theory and in case of hydrogen also it is not 5 line, but at least 3 lines you are getting.

So, in some extent it is also successful, but it is there is a problem. So, these line from 3, 3 p 2 3 s transition this is 3 p this is 3 p. So, 3 p to p s this transition 3 p to 3 s this transition these are yellow light it is a very bright light and very famous light in laboratory. So, it is called d lines it is called sodium d lines this line is called sodium d lines. And it is wavelength is I think 5893 angstroms 5893 angstrom yeah most probably I think. So, yellow light 5 to 9 5893 angstrom.

But when it is observed in higher in microscopy of high resolution in spectroscopy of high resolution then it is observed that this sodium d line it is not a one line it is basically a 2-line sodium d 1 and sodium d 2 lines, sodium d 1 and sodium d 2 lines, these lines is not a. So, these are d lines d line and this line is not a single line it is basically it is a 2 lines

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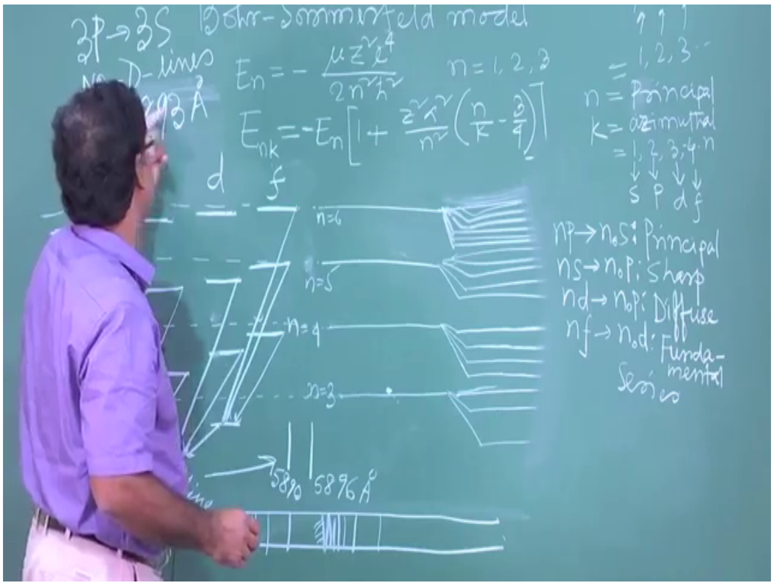

For wavelength of these 2 lines one is 5890 angstrom and another is 5896 angstrom. So, average is basically 5 8 9 3 we write for sodium d lines

So, sodium d lines is basically composed of 2 lines which are the separation is the 6 angstrom and that that wasn't observed earlier, but in higher resolution of spectroscopy. So, it was it was found that it is a 2 2 lines ok so, but why what is the origin of 2 lines that cannot be explained from this Bohr sommerfeld energy expression. So, this is one indication that whatever line now we are getting more lines, but still it is not sufficient and it cannot explain the say origin of this this d 1, d 2 lines it cannot explain the fine structure of sodium h alpha line it is how it is composed of 5 lines it cannot. So, here so far it cannot explain the origin of Zeeman effect when applied electric magnetic field. So, each line is splitted into 3 lines in case of in case of normal Zeeman effect, but in case of anomalous Zeeman effect for weak magnetic field. So, is splitted into even more lines

So, from where this lines are coming. So, that was not able to explain. So now, that people started to think about the more quantization. So, that in last class I started to tell you that about the another quantum condition was applied the space quantization. So, I will discuss in next class.

thank you.