Atomic and Molecular Physics
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Lecture - 21
Atomic spectra

So, we are trying to explain about the Fine Structure of atomic spectra.

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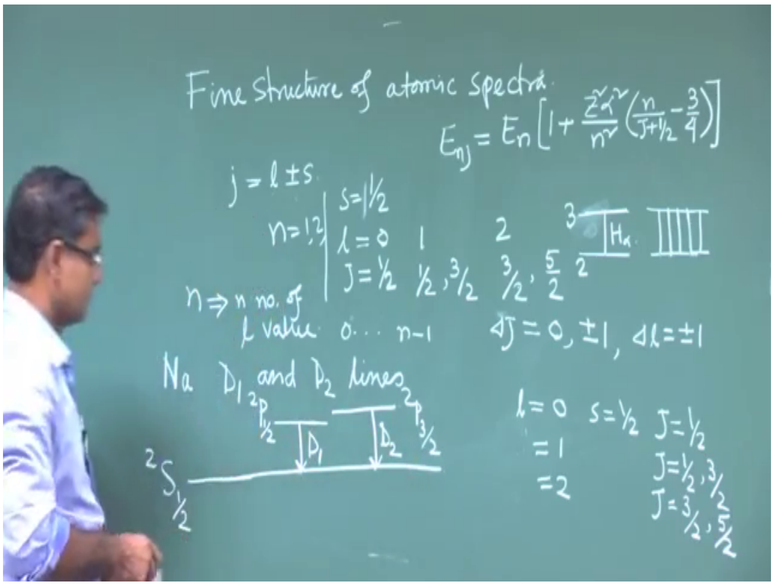

So, we have considered single electron system and we have seen that that energy E n j basically that is E n 1 plus Z square alpha square by n square; Then, n by J plus half minus 3 by 4. So, that was the energy expression which depends on basically only on n and j and what is j? j is j is l plus minus s or single electron system; 1 electron it has l angular momentum and it has spin angular momentum. So, they coupled l s coupling due to l s coupling it gives the resultant j. So, j value can take l plus minus s.

So, so for single electron s is half; s equal to half ok, s equal to half. So, now, depending on l, depending on l l can be 0 or s orbital. So, then, J will be for this J will be half ; then, for l equal to 1; j will be l plus minus half means l is 0, l is 1. So, a J will be half or 3 by 2 or 2. It will be 3 by 2 or 5 by 2. So, they say one can find out J value for corresponding depend l value. And this can be for any n; n equal to 1, 2 depends on.

So, it does not matter whatever the n value, but for a particular n value for a particular n value. So, it will have n number of l value, n number of l value starting from 0 to n minus 1 right, that we have seen. And we have explained the fine structure of H alpha line of H alpha line.

So, H alpha line; So, this it is basically for n equal to this transition between n equal to 2 and n equal to 3 and then, its splitted into 5 lines as the this H alpha line is composed of 5 lines and that 5 lines from the transition considering this energy expression which depends on J and selection rule, we have considered del J equal to 0 plus minus 1 right.

And del l equal to here we do not need, but it is a plus minus 1; that is the another selection rule and also we have seen the we have seen the origin of the Sodium D 1 and D 2 lines.

So, that for sodium outermost electron was in n equal to 3 right. Now, for n equal to 3. So, l will be 0 1 2; l will be 0 1 2 l will be 0; so, these for sodium D 1 and D 2 lines. So, it is a outermost electron is at n equal to 3. So, you will you will get basically for n equal to 3 ah; you remember that for l equal to 0, this is the s l equal to. So, there are 3 possible value, l equal to 0; l equal to 1 and l equal to 2 ok. So, and s is half 1, 1 electron. In outermost it is 1 electron. So, s equal to half ok; So, your J value J will be half and in this case l equal to 1.

So, this J will be J will be half and 3 by 2. Similarly for l equal to 2, J equal to 3 by 2 and 5 by 2 ok. So, this term basically. So, l equal to 0 means is s, I will get term for l equal to 0 it will be I think let me write here. So, for n equal to 3; so, what are the term I will get? I will get l equal to 0. So, this is S and S equal to half multiplicity 2 s plus multiplicity 2 s plus 1. So, it will be 2 and J equal to half. So, this is one term. So, it will have 1 energy level and then, l equal to 1.

This is term P. So, P will have, term P; P will have 2 J value half at 3 by 2. So, this also 2; this is one half. This one term and another term, now which energy will be lower for same s, for same n value, n equal to 3. So, that we have mentioned that when J will be higher. So, this term will be lower ok. So, this term will be lower. So, 1 plus this it will be lower value.

So, smaller J lower energy ok, smaller J it is it will be more negative and higher J this value will sorry yeah higher J this value will decrease. So, it will be less negative. So, 2 P half and then, another energy level he will get.

So, that is 2 P 3 by 2 right. So, transition basically from this level, to this level; so, this one is D 1, another is D 2 ok. So, earlier this when J was not considered; So, this 2 value D 1 D 2 was basically to us showing wall line. So, you will get D 1 D 2 because of this, l s coupling that resultant j. So, now that also we are able to explain. Next, what we want to see that that Anomalous Zeeman effect whether we can explain Anomalous Zeeman effect.

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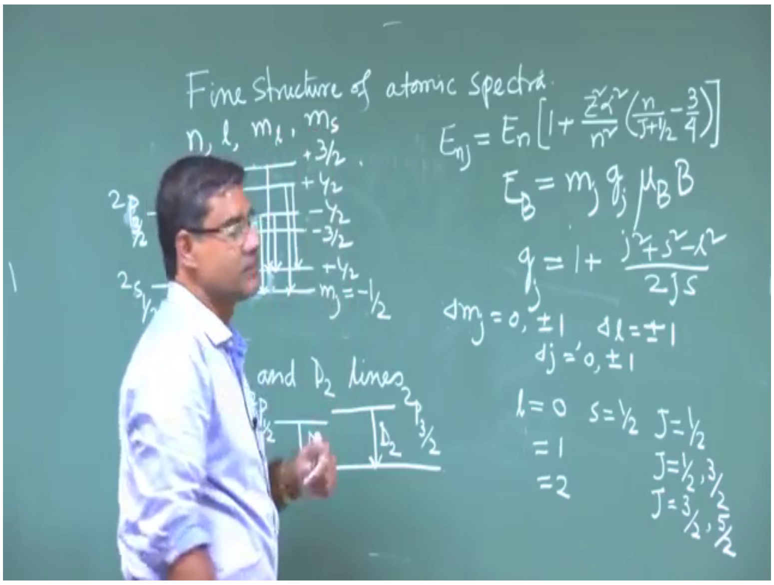

So, normal Zeeman effect we have seen, any lines its it can it is it breaks into 3 lines, that is normal Zeeman effect. But in Anomalous Zeeman effect. In anomalous Zeeman Effect; so, different lines it is split into in different number of spectral lines. So, let us check just sodium D 1 and D 2 lines. So, sodium D 1 d 2 lines here, you can see the sodium that a D 1 lines, it is it is basically transition between these 2 s half and 2 s 2 P half right.

So, this transition; Now, when you apply magnetic field small magnetic field then, what happens? That is what we want to see. So, there will be change of energy due to magnetic field. So, that energy this similar as we have seen earlier so that energy additional distant pass this additional energy due to the magnetic field.

So, that is m j g j mu B B mu B B. So, earlier we have seen in case of m l or m s, we have seen. So, in that case for m l g l that value was 1; m a g s that was 2 and now g j is different value. What is the g j value? That we have derived. So, that was 1 plus j square plus s square minus l square by 2 j s ok. So, for these 2 term, what is the j value, what is the l value and what is the s value that we know and we can find out g j. Now, what are the m j value for a particular j value m j value again minus j 2 plus j ok. So, here j equal to j equal to half.

So, its m j will be plus half and minus half m j will be plus half and minus half see, it will be split into 2 level ok; m j equal to minus half m j equal to plus half ok. Similarly P, here j also half value. So, its m j m j again 2, see it will be split into 2. So, what you will get?

Here it is minus half and this plus half ok. Now, here we have to consider this transition; this selection rule in this case you have to consider m j equal to 0 plus minus one and del J equal to 0 plus minus 1. So, del J already we have considered. Now we have to consider the m j value. So, here you will see this transition is possible let us take.

So, del J has to be different and also one has to consider this see del l equal to plus minus 1 and del J equal to 0 plus minus 1 ok. So, here transition between these 2 is not possible because it will violate, we saw same l ok. So, transition only possible between these 2. So, that is fine, already we have considered. So, here transition between this level to this level we have to consider.

So, this transition is possible because minus half minus half say its del m j is 0 and then, from here minus half to plus half also, it is allowed because del m j equal to plus minus 1. Similarly, from here this plus half to minus half also allowed, also allowed and from here this plus half to plus half this also allowed ok.

So, now, we can see this D 1 line, it is splitted into it will be splitted into 4 lines and experimentally it is seen that its dual line it shows this shows these 4 lines and their wavelength exactly match with the experimental value. Similarly, one can show that this when you will consider the D 2 line. So, we split it into 6 lines, it is splitted into 6 lines. So, here itself I can do. So, D 1 for D 1 it was P half to s half that transition and D 2 transition P 3 half to s half.

So, now it is D 2 line earlier, we considered D 1. Now d 2 lines now here this is fine, but this one now J equal to 3 by 2. So, m j will be minus plus 3 by 2 to minus 3 by 2. So, we will have 3 value, 3 by 2, half, minus half, minus 3 by 2 m j value. So, we will get more 2. So, this is minus 3 by 2 m j value and let me erase it. And then, I will get another value that is plus 3 by 2 because higher m j value energy will increase, higher m j value energy will increase ok.

So, this is the highest energy ok. So, and this transition also it is possible to see these 2 lines cannot have the same energy because of the g j value because g j value will be depends so, this splitting will be asymmetric we know earlier in case of m l, this splitting was symmetric.

So, we have seen that line 9 lines for H alpha line, see it is basically 3 lines and that was because of this symmetric splitting. Now, this asymmetric splitting because g j value will be different for different j value ok; although s and l value same, but j value are different. So, g j value will be different and then splitting will be asymmetric ok.

So, in this case now you see. So, now, this transition will be allowed whatever we have seen already. Now, additional you see I have 2 more lines minus 3 by 2 and plus 3 by 2. So, minus 3 by 2 to half this transition is not allowed because it will be 2 del m j value will be 2, so is not allowed. So, this is the final minus that initial. So, plus half minus half minus 3 half; so, it will be 2. So, this is not allowed. So, minus 3 by 2 to this minus half, it is allowed it is allowed.

So, del m g value will be plus 1. So, this will be allowed. This will be allowed and from this level plus 3 by 2 to minus 3 by 2 this is allowed because minus 3 by 2. So, it will be minus 1 del m j. So, this is also allowed. This is also allowed ok. Sorry, this is also allowed up to this. But from here to this minus half, it is not allowed because minus half minus 3 by 2. So, it will be minus 2. So, that is not allowed. So, now, you see these 6 lines. So, and experimentally it is found that sodium D 2 line is splitted into basically if 6 lines ok.

So, what we have seen that this considering the spin angular momentum and then, they are coupling l s coupling giving resultant angular momentum j that is that is quite successful to explain the all Atomic spectra, whether it is fine structure or it is Zeeman effect basically Anomalous Zeeman effect.

Normal Zeeman effect also is explained there is considered that when there is no existence of and for that we have seen that we do not need to consider spin only l considering l and m l. So, that was sufficient to explain reaching is that this at high magnetic field, this l s coupling basically breaks. So, that coupling do not exist. So, there is no coupling there is no j ok. So, individual s and individual l, they are independent.

So, already we have seen that considering only l one can explain the normal Zeeman effect and s is there in presence of s, it will not affect. It will not affect because this energy that it depends on n l and whatever due to s. So, that will not affect the transition. So, thus these the complete quantum number so far we have got.

So, what the quantum number we have got? For single electron n and then, l and then, m l and m s; So, if you do not consider the if you do not consider the l s coupling; then, these 4 quantum number is sufficient to explain to explain the most of the properties and one has to consider the j in that case, then in that case we consider that when we are considering the m s l s coupling. Then, one has to consider j value instead of l value; one has to consider j value.

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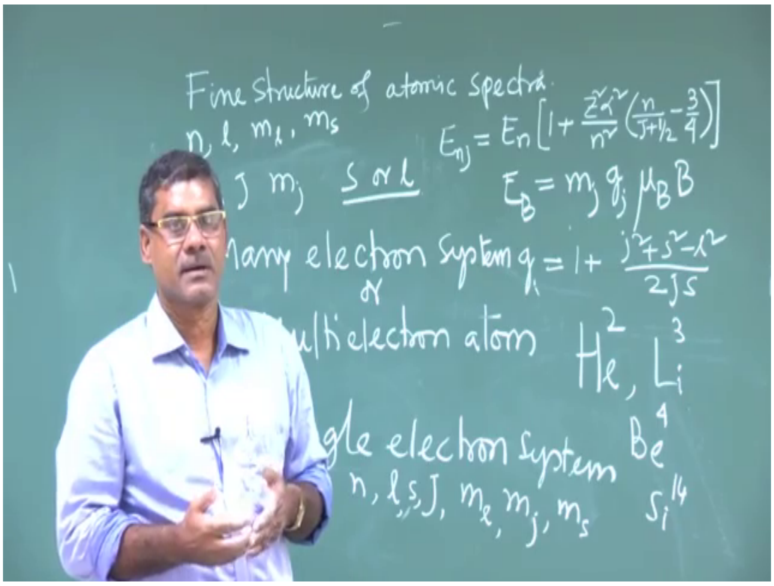

Then, that is n; J, m j and I think this 3 are sufficient. These 3 are sufficient n, J, m j value ok; m s one we have to know I think yes.

So, yes; So, n, J and m j, these value are sufficient. Basically, these 3 value will be sufficient. If I know the I have to know the g j. So, either one should know s or l. If we know s or l and then, other one can be find out other one can be find out ok. So, so these the these the basically picture of single electron system so far whatever we have considered.

So, that is for single electron and for single electron, we have explained the different kind of different kind of spectral lines that is whether in presence of electric field, whether in presence of magnetic field or in presence of without any electric or magnetic field is normal ok. Now, we would like to we would like to study about the many electron spectrum ok. We would like to study about the many electron spectrum for multi electron atom. Many electron spectrum or we tell multi electron atom.

So, more than 1 electron in atom; So then, what about the spectral lines of those atoms? So, so far we have seen the spectral lines for single electron spectrum. We have studied the single electron system and there we have we have seen that what is n, what is l and what is J , what is m l; what is m s m j.

And then, let me write this is s. This is J, m l, m j m s right. So, here 2 aspect; one is when there is no l s coupling electrons are this angular momentum are independent ok, this is one aspect. Another aspect when there is a coupling between angular momentum and the spin momentum. Then scenario is different ok.

So, in most of the cases, it is this coupling is observed coupling is observed and considering the coupling, considering the resultant j value and we have seen that one can explain all phenomena of spectral lines and this Atomic spectra study of Atomic spectra basically spectroscopy of atoms. So, that is very helpful to study to find out the structure of the atoms structure.

What is the structure of atoms? We have nucleus, then electrons are surround surrounded. So, how they are they are rotating or revolving around the electrons, they around the nucleus? And. So, they are rotating in different energy level ok; different orbits, orbitals and this orbit, orbitals they if what is their energy. So, that everything we have studied.

So, now if we take Helium atom ; see it has 2 electron, basically it has 2 electron right and then, lithium is basically alkali atom. So, in case of lithium alkali atom that is equivalent to 1 electron that we have seen earlier. So, it is multi electron, but it behaves like single electron. Why that we have explained. So, these then, Beryllium, this 4 electron.

Then, if you can take any one say silicon. It has 14 electron ok. So, now multi electrons; more than one electrons for them, how we can study the atomic spectra or how their structure; how the electrons are arranged in the atom? So, that we would like to study; So, I will continuing in next class let me stop here.

Thank you.