Atomic and Molecular Physics
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Lecture – 22
Atomic spectra (contd.)

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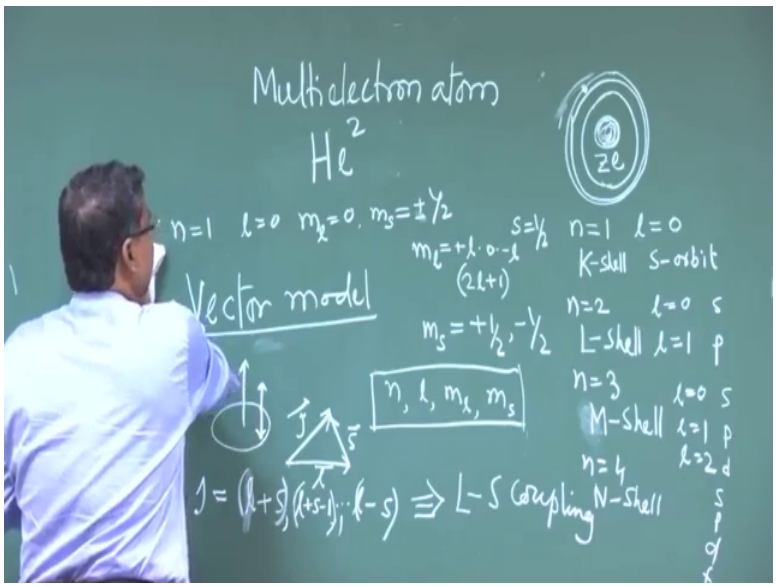

Except this hydrogen atom or hydrogen like atom means hydrogen or hydrogen like atoms means is ion basically say helium ion ok. It has two electrons, but is it is one electron is taken out. So, one electron is; so it is basically ion, one electron has taken out. So, it is single positive ions.

So, for such system we are considering nucleus we have considered nucleus ok. So, that is Z e; Z e and outside only one electron outside only one electron outside only one electron. So, what are the orbits or orbitals exist in the atom. So, there these electrons can revolve ok. So, that we have studied there are different different orbits. So, that we have seen n equal to 1 ok.

So l equal to 0 ok; so that is this we tell K-shell n equal to 1 K-shell and S l equal to 0 S orbit. So, this we tell this; this gives K-shell or k orbit K-shell and this corresponding l equal to 0, this S orbit or sub shell S orbit or sub shell, right. So, this say it is n equal to 1 it is 1; n equal to 2, then this we are telling L-shell and corresponding l equal to 0 and l

equal to 1 ok. So, this it has S sub shell S and P sub shell or orbitals l orbit P and S orbitals.

So, similarly for n equal to 3, we have seen l K and l M-Shell and corresponding l equal to 0, l equal to 1, l equal to 2, so S P d S P d sub shell right. So, similarly n equal to 4, we will get n equal to 4; we will get this is N-Shell and here we will get S P d and f, S P d and f right. So, so then we have seen that; so electron can be; so here basically it has two sub shell it is not one, it is basically two ok. Similarly; so it is not circular it is elliptical shape S will be when n equal to; this for all S orbit orbitals that will be the spherical; otherwise all PDF; they are not spherical elliptical ok.

So, now, one electron having two angular momentum l and S, so all the time in this case S equal to half for all cases S equal to half ok. And now we have seen, when it is quantized in space for l value so, this quantized in space that gives ml value, this gives ml value, so that ml is basically minus plus l to minus l, plus l to minus l in between 0 will be there. So, it is gives 2 l plus 1 number of number of ml values and or S half, it will have two space contraction one for spin angular momentum. There will be two space contraction one is plus half and another is minus half plus half, it is a parallel to the fixed direction space and minus half it is anti parallel to the fixed direction ok.

So, half S will get ms plus f or minus f plus f or minus f ok. So, this electron wherever it is wherever it is; it will so, we can specify the electron with this quantum number with this quantum number. So, so to specify this we consider what is it is n value? What is it is n value, and then what is it is l value, then what is it is ml value and ms value ok. This 4 quantum number; using this 4 quantum number, we can specify the state of an electron where it is. So, it can be anywhere it can be you know there are many sales orbitals; it can be anywhere.

So, to [vocalized-voice]; to specify that one, to specify that one; we take this 4 quantum number. When we take when we do not consider the coupling L-S coupling; there is quantum; this angular momentum; they are independent. We consider that they are not coupled ok. So, when we consider their couple, then scenario is different ok. So, so for 1 electron for one electron; what are the states we can get it can be n equal to 1, l equal to 0, l equal to then 0, then ml is 0 and ms can be plus half or minus half, it can be for this case, it can be plus half or minus half ok.

So, either plus half or minus half that one has to consider; so, corresponding basically S is half it is spin is half. So, when spin is half; so it can have two steps plus half or minus half right. Now when we consider coupling when we consider coupling so as I mentioned that we use the vector two model, how they are couple how to find out. So, we use the vector model, vector addition is it is called vector model very useful model vector model.

So, using the vector model one can get the resultant one can get the resultant; basically angular momentum. So, so I have I have electron. So, it is it has angular momentums ok; that means, electron is rotating like this. So, it is angular momentum l is same this l is this and then it has also spin angular momentum. So, it is spin is also it is spin is say in this direction or it can be it can be S.

So, now, l and S it is vector, it has magnitude as well as deduction ok. So, if you add them so just break the rules on use ok, if it is l, if it is S; then this will be J. So, they are resultant as J. So, that I have discussed; so here when they are aligned so; obviously, there will be; their magnitude will just simply just it will be add it same deduction, since they have been same deduction; so J plus S whatever J where sorry l value l plus S ok.

And if extreme; another extreme case it can be it can be just in opposite direction is just anti parallel to this l. So, in that case it will be l minus S magnitude will be just l minus S right. And other value depending of their angle, if angle between l and S it is not 0 where it is 0.

So, magnitude it will be l plus S, and when they are anti-parallel so magnitude between l minus S, then it is 180 degree basically; angle between this to 180 degree. For other cases depending on angle you will get the result at. So, that resultant is it one; we will get from this required addition; so, l plus S minus 1, l plus S minus 2 etcetera; so up to l minus S.

So, that I hopefully I mentioned in earlier class ok. So, this basically is a J value, this will give the J value and corresponding resultant it will have deduction also, but this the magnitude these are the magnetism any have. So, l plus S to l minus S; so that is the J value, that is the J value and this is this is basically called L-S coupling L-S coupling.

So, now in case of multi electron, this concept is extended. Now, if I have two electron, now if I have two electron. So, then what will happen; in case of two electron say helium say helium it has 2 electron. Now 2 electron each electron is having, each electron is having it is own angular momentum; either orbital angular momentum or spin angular momentum each electron will have their it is own angular momentum orbital and spin angular momentum.

So, now, I can write I can write; so, helium I have taken as a example; it has two electron ok, but if I take I will show you that there is a difference between that helium, two electron and any system having 2 electron; so that I will tell you later on equivalent electron and non equivalent electron. So, I will come to this point later on, just let me in general let me tell that now multi electron, so if I consider two electron; two electron system, so each electron have it is own angular momentum; orbital angular momentum or spin angular momentum.

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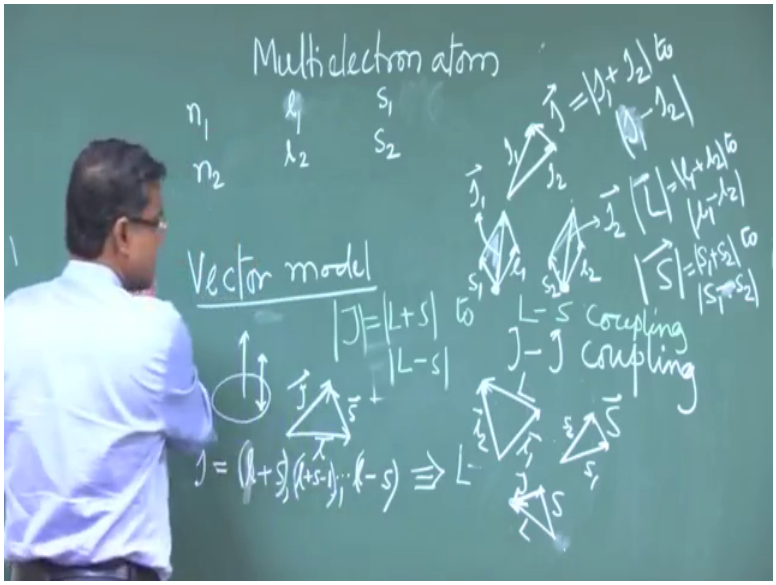

So, what I can do. So, it is whatever it has some n value. So, n 1 for electron 1, n 1 equal to say 1, n; sorry l 1 equal to; obviously, to 0, if n is 1, l will be 0. So, now, whatever n l ml ms. So, now, I am writing for fast electron as 1 l 1. So, then; obviously, is S 1 equal to half ok; of this electron, then you have a ms 1 will be plus minus half and ms ml 1 it will 0.

So, I think this I will not write now; let me come after this. So, what I want to find out this using the vector model, what will be the J value right? For two electron system for one electron system what will be the J value that I have shown in how to calculate? Now for two electron system, what will be the; so n equal to say it also 1.

So, l; l 2 so l 2 it can be it can be if it is n 2 equal to 1. So, if basically n 1 equal to n 2 so, now, l 2 equal to here, if I take 1 then it is 0 so, but in principle that electron it can take any value any value it can take any value of n. So, I will not write n equal to 1, it can take any another one can take any value of n. So, I will not write. So, this for electron one and this for electron two, second electron so it can take any value of l 1 other one l 2 say S 1 say it is half of course so let me not mention it is spin is half and this other one is spin is S 2 ok.

Now I have two electron; I have two electron. So, it has l value it has S value so it is l 1, S 1 ok. Another I have another electron it has say l 2 and it has say S 2 ok. Now two electron in one atom it has 1 1 nucleus and 2 electrons in the systems. So, now, 2 2 so now, coupling we have seen for singular electron coupling have seen L-S coupling ok; l and s so this electron also have l and S.

So, I can get j 1; I can get j 1 resultant I can get j 1 right, I can get j 1 this one will be j 1, j 1 and this one will be j 2, this one will be j 2 this one select write here j 1 ok. So, this is one possibility that one electron. So, they couple this that electrons angular momentum spin and orbital angular momentum, they coupled and form to get the resultant angular momentum, that is j 1.

And for other one also ok; it is own this electron it is own angular momentum spin and orbit orbital angular momentum, they couple and form the resultant angular momentum j 1 and j 2. Now j 1 and j 2; so one is having say this deduction j 1 and another is having say the deduction j 2. So, this is j 2 and this is j 1; it is in same atom, it is in same atom; now two angular momentum resultant angular momentum j 1 and j 2 ok.

Now it may happen that they will again interact and give the resultant momentum resultant momentum. So, that one can get adding this vector addition of this 2, so this and this so, this can be this can be this.

So, this will be the resultant j, this will be the resultant j ok. So, vector addition so this j it can take value j 1 plus j 2 to j 1 j 1 minus j 2 magnitude just it magnitude [vocalized-noise] ok. So, this type of in multi elect miss system this type of coupling is called J-J coupling this type of coupling is called J-J coupling J-J coupling ok. So, this is one possibility coupling of angular momentum of two electrons, here I have shown if three electron,s four electrons what will be what will be the case .

So, one has to find out in this case for J-J coupling one has to find out j 1 for one electron, second electron j 2, third electron j 3, j 4, j 5 etcetera right. And then I will take the vector sum of j 1, j 2, then what are the resultant I will get then I will add with it that j 3, I will add right vector addition, then what about the resultant j 4 I have to add. So, that way vector sum addition one can do and get the resultant j of this multi electron atom ok.

Similarly, other case may happened that before instead of L-S coupling in dependent in individual electron it may happened that, there two electrons are there; now theirs orbital angular momentum is coupled so; that means, l 1 and l 2, l 1 and say l 1 and l 2 are coupled vector sum you can get. So, you will get L. So, let me write with capital letter ok. So, now, that is the resultant l of the angular momentum of the of the two electron system and spin S 1 and S 2 they are coupled.

Spin angular momentum is coupled so this one and say this one so, S 1 and S 2 they are coupled. So, you will get the resultant S capital S right. Now two electron system, now it is total angular momentum l capital l total spin momentum capital S, total spin angular momentum capital S. Now they will; now this resultant l and resultant S, they if they coupled then I will get j resultant j.

So, so here if it is l, if it is l ok; if it is l this l deduct l and then if it is S, if it is S capital S, then I will get the resultant say this one. So, I will get resultant angular momentum that is j capital J ok. So, now, the j capital J this; what will be the capitals say here; what will be the l value? So, vector sum vector addition l like similar way one can write capital L capital L that will be that magnitude of that will basically l 1 plus l 2 to l 1 minus l 2 magnitude ok.

Similarly, for S capital S magnitude will be S 1 minus S S 1 plus S 2 2; S 1 plus S 2 S 1 minus S 2 S 1 minus S 2. Similarly, here for j vectorial sum this same way one can tell

that j will be j will be j will be capital J will be magnitude of this will be it is l and S. So, l plus S to l minus S so this called basically this called L-S coupling this called L-S coupling ok.

So, here I showed you that J-J coupling, and then other one this if it is resultant j if we get this way here also you are getting j resultant j resultant j; other case also your getting resultant j. So, if you get this way, so then it is called L-S coupling. So, then it is it will be called L-S coupling. So, both are possible in multi electron system both are possible in multi electron system, but in one electron system there is no question of J-J coupling and L-S coupling in that since ok, but this term this are used basically useful for multi electron system J-J coupling and L-S coupling.

What is J-J coupling; that I explained. What is L-S coupling; that also I explained. Now, most of the term shows the L-S coupling; most of the atom multi electron atom shows the L-S coupling only heavier atom z value is very high only few heavier atoms, they shows the J-J coupling they shows the l and j coupling. So, that is why mainly we concentrate we will concentrate on this L-S coupling not J-J coupling ok.

So, this is the basically vector model. So, we have considered two electron. So, if three electron, four electron, five electron so same way one can find out. So, this is for l is two electrons, so if I take third electron, so this l 3 I have to add with this l ok, then I will get the resultant l similarly S and then we will get j for three electron system, four electron system, five electron system ok. So, I think I will stop here and then I will continue in next class.

Thank you.