Atomic and Molecular Physics

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Lecture - 18
Structure of an atom (Contd.)

So, we will start considering the spin angular momentum. So, far, what are the quantum number, we have seen that is n that is the principal quantum number ok.

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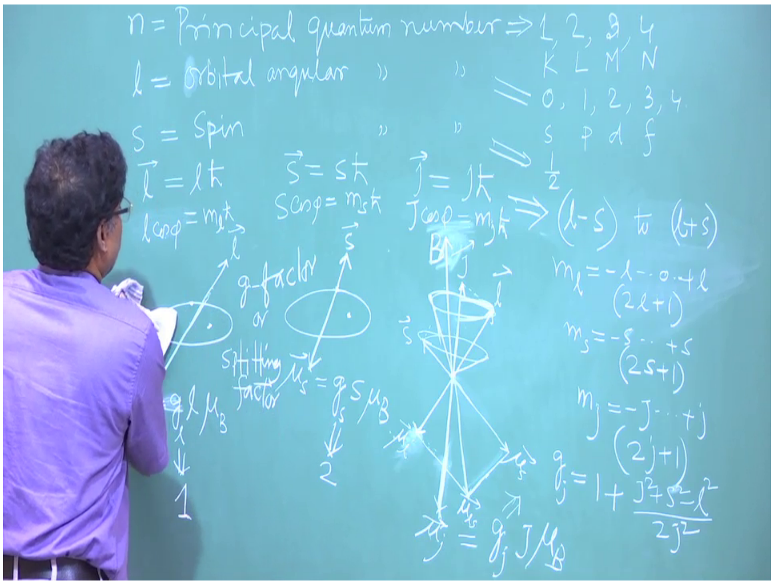

So, you can take value 1, 2, 3, 4, 5 and corresponding is 1, 2, 3, 4, 5, etcetera and this we tell K shell, L shell, M shell, N shell, right and then angular quantum number and imphal quantum number. So, the better, we should write because we have another quantum number that is a angular spin quantum number.

So, this l we tell is orbital angular quantum number. So, this l value it takes for a particular l value, it can take 0 1 2, 3, 4, etcetera. So, its name is given is p d f g etcetera. So, then we got the other quantum number, it is the spin quantum number, this is also angular momentum spin angular momentum orbital angular momentum. So, spin quantum number spin quantum number and this it can take value of it can tell take value of, and then 2 more quantum number, we have seen that that is basically active that is basically active for when we apply magnetic field or electric field some external agency we apply.

So, that was I will write that later on one is ml and another one is ms; so, corresponding here ml, ms are there so that is a above to fixed direction in space that direction is realistic in the direction of the external magnetic field or electric field ok so that I will come later, so, without magnetic field or electric field or external agencies. So, what are the quantum numbers?

So, these 3 are the quantum number now we have seen the quantization relation we have seen the quantization relation this for l, we have seen for l, we have seen l angular momentum, it is quantized this is l h cross l is magnitude, and l can take value as I told and then similar S s, we can write swing arrow S s cross S can take value of.

So, here this l angular momentum; so, this basically electron; so, it is a direction of the angular momentum is you can take this l and this l. Now, it is for the particular orbit its fixed its normal to the plane now then you are saying this now orbit this in space is quantized. So, it is giving ml so that I will come later now in this of S also electron; so, it has spin motion and for that will spin angular momentum so, it also direction s, right. So, now, for same electron there are 2 angular momentum.

Now, question is that whether they are independent or they are coupled actually they are coupled is called ls coupling is called ls coupling ls coupling. So, l and S there are they are not independent they are coupled together and keep the resultant angular momentum. So, when they coupled they keep they give the resultant angular momentum. So, that is the that called total angular momentum it is represented by J it is represented by J ok. So, l is n J j is the total angular momentum and representation of this J is basically it is a. So, I I will not draw this orbit.

So, electron one electron it is an orbit it has angular momentum orbital angular momentum spin angular momentum and then due to this ls coupling we will get the total angular momentum. So, how they are coupled question is how they are coupled so that we can consider that. So, this electron is the say orbital angular momentum and say this is the spin spin angular momentum ok. So, now, they are coupled and the resultant J. So, these 2 are vector basically right, their direction and their magnitude is half and this l have different magnitude depends on.

So, now say it is l magnitude; so, now, resultant one; so, vectorial addition, we can get this resultant angular momentum so that will be basically this so that is J; that is J we write here that is J; that is J. So, from vectorial addition, we can get the resultant angular momentum. So, it is not applied only for this case ok so, for as a whole this vectorial addition it is applicable in many cases of this for this atom. So, actually this model was developed is called vector model of an atom. So, this is one part of that. So, vector model of at very famous model successful model vector model of atom because considering this model actually when.

So, so far we have we are discussing only one electron system hydrogen atom or hydrogen like atom or alkali atom because it has similarity with the hydrogen atom or electron system. So, these are the one electron system, but for many electron system when atom is having many electrons. So, each electron will have angular momentum spin angular momentum orbital angular momentum. So then also for individual electrons they have this momentum whether they are coupled or individual. So, that question also will arise and we will see that yes they are coupled and following the vector model one can explain the structure of the atom of many electron system.

So atom having many electrons for that this vector model is very successful model, so, this under this model one can consider that we found this total angular momentum from lns of a one electron system ok. So far for l this is the l equal to l h cross for S S h cross. So, this J is called total angular momentum and this similarly this J will follow the same way into see it. So, now, another angular momentum is total angular momentum. So, this also one can write this same way J S cross now what will be the value of j. So, this J is total angular momentum this J value it will take l minus S to l plus S it will take l minus S to l plus S.

Now, you; so, here let me discuss more this how they are coupled how this l is coupled. So, it is telling that this l will precise will precise l will precise taking J around the J taking J axis it will precise ok, it will precise this J will precise I think I should I should grow symmetrically. So, it is form a cone basically. So, above this axis J will precise like this. So, J will precise l will precise this taking the J axis. So, around the J, l will precise around the J S will precise S will precise around the J S will precise.

So, thus they are coupled with J. So, into this precision they are coupled with j. So, J value I have as I told this it can take l minus S to l plus S. So, then if I come to the similarity, if I come to the similarity, next one is basically ml. So, ml value ml, it can give it is nothing, but a space quantization and I think it is a how it is it can it is l cos phi l cos phi, right that was quantized. So, that was ml S cross similarly S cos phi it is m s s cross here also that J cos phi cos phi.

So, this is about a about a constant direction right in space see you can take as a field direction say magic field direction. So, they are making angle this phi this also making angle phi, but its phi is variables. So, initial angle may not be same, but they are in spaces. So, space quantization. So, J cos phi it has to m J S cross. So, is a see it is a angular momentum or the angular momentum. So, it will for the; we can follow the same way for all cases. So, what are the ml value ml value ml value you can take minus l to 0 plus l plus l.

So, 2 l plus one it is the number of ml values; similarly, S value that is ms. So, it can take minus S 2 plus S since it is half. So, it will also take 2 S plus 1 2 S plus 1 since S is half only this value is allowed for one electron. So, it will be ms will be 2 ms will be 2 plus or other minus 1 and then similarly 1 can write mj mj, it will take value minus J to plus J it will also 2 J plus one value it will have also 2 J plus 1 value.

Now, magnetic moment magnetic moment for ml; so, the magnetic moment as I mentioned this S cross is opposite direction we write for l corresponding this will be ml it will be in opposite direction. Similarly, it will be opposite direction, this S, this also it will be in opposite direction k; so, it will be J in opposite direction. So, later on I will see magnitude. So, this is mu J this is mu J right. So, here is what relation we got ml equal to l mu b l mu b. So, let me write here gl gl and mu S was. So, it was gs gs S mu B; S mu B ok. Similarly, mu J mu J, it will be mu J it will be g, J J in same way I have written in same way I.

So, gl value is basically we have seen this is 1 gl value is one gs value is taken this.. So, this g is called is called g factor is called g factor or splitting factor is called g factor or splitting factor, why it is called that I will we will see later on. So, g factor g is called g factor. So, g is called basically g factor or splitting factor splitting factor ok, it is called g factor or splitting factor right now if I considers; so, this I have seen S.

Now, here this one is gs we have taken 2 for experimental because here is we have seen this electron this dp spin, it is a magnetic moment in physics magnetic moment is basically mu v; so, it is half gs 2. So, it may be and here it is l mu b for l equal to 0 it is 0 l equal to one it is mu b l to 2 it is 2 mu b etcetera, but here will we will discuss later on and let me first find out what will be the value of gj what will be the value of gj gj value is not 1, 2 or 3 it is different value. So, gj value I can write now, but I will derive it.

Gj is basically one plus one plus J square plus S square minus l square divided by 2 J square 2 J square gj value is one plus J square plus S square minus l square by 2 J square. So, that that how it is coming that I want to show now; so, for that; so, this is J corresponding magnetic moment mu J, now this is l corresponding magnetic moment mu l mu l; this magnitude will be same in terms of mu b. So, this is mu l in opposite direction and this is S; so, corresponding sorry; so, what about the magnitude here is equal to half basically. So, but here it is not half maybe it is mu b. So, this magnitude will be doubled in terms of mu B magnitude will be doubled.

So, this and this; so, this is more or less this or this will be the mu S, now vectorial addition of these 2 vectorial addition of these 2 will give you vectorial addition of these 2 if I and then this S S more or less more or less it is. So, vectorial addition will be this and then if I just. So, here we can see the direction of mu J and direction of the vectorial addition of these mu S and mu l are not same. So, this we tell nearly mu l S mu l S.

So, mu l S is different from the mu J here this vectorial addition will give an J a corresponding mu J and now if we consider the individual mu l just opposite to l mu S opposite to S. Now, resultant of this mu l and mu S is mu l S then that magnitude and direction is not same as mu J it is different. So, I think I will I will erase it; so, now, you see if I want to find out mu J.

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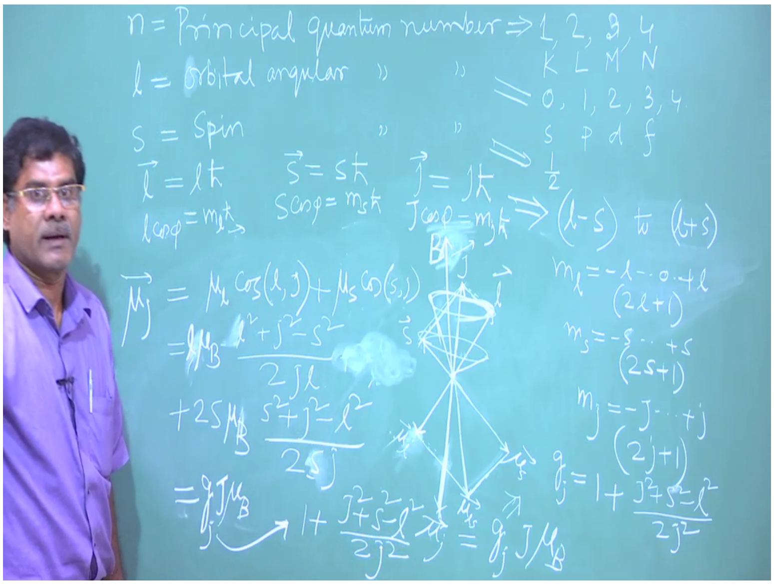

So, mu J; so, mu J; now you can take the component of mu S along this along this J direction along the J direction all right; so, mu J we have to we can to we write mu S.

Let me first write mu l I can write mu l component of this around the mu J direction or J direction. So, this will be mu l angle between l and angle between l and J angle between l and J right plus mu S angle between mu S; S angle between S and J mu S angle between S and J or mu S and mu J so, that will give S J ok. So, from here mu l we can to mu l we can to l mu b sorry l mu b right. So, J l J l is 1 plus this cos l j; so, cos l j; so, it will take it is tangent plus ok. So, this cos value you know this. So, it will be l square. So, what are the; what are the.

So, here l S and J l S and J if angle if we considers l S and J. So, S what will be the angle cos l J and S. So, that angle you can you can write it is angle opposite to this which one is the angle lj lj, this is the angle right, this is the angle and this will be S, this will be S 1 is l 1 is J and this will be the S right, this will be the S; so, this will be the S. So, cos J l l squares this cos J l, this will be l square plus J square minus S square divided by 2 J l right plus mu S plus mu S.

So, mu S is I can write S mu B gs S mu B right that we have written gs S mu B. So, gs S mu B. So, gs is 2 h is half that is why we write this is only mu b or no. So, we will write to S mu B g S mu b. So, S is half S S is S is there gs is 2. So, I will write in 2 S because gs is always two. So, then angle cos S J cos 2 n J cos n j; so, this, so, you can consider this; so, one. So, J S at opposite one is l. So, this angle is just opposite to l. So, it will be we can write here so, plus 2 S mu b 2 S mu B S J. So, I will get S square plus J square minus l square divided by 2 S 2 2 to S J S 2 S J.

Now, if you just simplify it is done just you simplify it one step you will get. So, you have basically a mu b you have mu b you have mu b and then you will see from here itself I think J will come because J is everywhere is theirs J is everywhere in theirs and from here you will get gj some constant gsj and gj will be this. So, I am not doing the next step just please do it and then you will see gj jmb where gj will be one plus J square plus S square minus l square divided by 2 J square. So, if you just do the next step.

So, I have derived it ok. So, I got the relation for gj and now everything in our hand, I think; these are the sufficient these are the sufficient quantum number in our hand and next we will try to see whether this number of quantum quantization can explain the file structure of atom. So, I will stop here in the next class I will explain it.