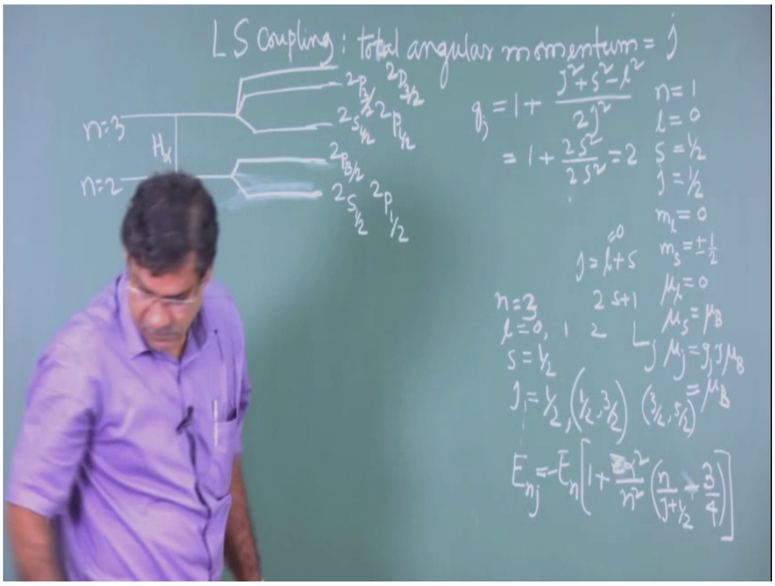
Atomic and Molecular Physics
Prof. Amal Kumar Das
Department of Physics
Indian Institute of Technology, Kharagpur

Lecture – 20
Structure of an atom (Contd.)

So, in last class what we have seen that.

(Refer Slide Time: 00:22)



Is LS coupling and corresponding total angular momentum that j ok so, for 1 electron system; hydrogen or hydrogen like atom. So, 1 electron say n equal to 1 then l equal to it is 0 in l, then s equal to half j equal to l minus s to l plus s. So, this 1 electron system this is half and m l l equal to 0. So, m l will be also 0 m s it will be plus minus half right plus minus half, then for this electron 1 electron see will get mu l that is l equal to 0, l equal to 0.

So, this mu l is l mu v. So, l equal to 0. So, mu l will be 0 mu s l to g s s may be g s to s half. So, it will be mu B. So, far any electron it is all the time is magnetic moment is mu B and then mu j mu j is g j g j j mu B g j j mu B. So, g j 1 has to find out g j 1 has to find out g j is 1 plus j j plus 1.

So, let me write for simplicity j square plus s square minus l square divided by 2 j square. So, what in principle one should write j j plus s s plus 1. So, but just for simplicity I have written out. So, calculation will be I think simpler. So, here j is mu j I have j is half is half l 0. So, l 0 and then you are j j equal to l plus s j equal to l plus s j equal to l plus s.

Make to a sums it become l plus s plus 2 s l minus s. So, here l is 0. So, j can have already s value. So, this basically 1 plus j equal to s 2 s s square get by 2 s square because j equal to so, this is 0. So, j equal to s. So, it is. So, g j equal to 2 ok. So, it is mu will get. So, j equal to half g j equal to 2. So, then it is 1. So, mu j also it will be mu B ok, because why it.

So, because l is 0 there is no practically there is no ls coupling because l is 0. So, there is no l s coupling. So, that is why this whatever for s value mu s what 1 mu s so, mu j also will be same ok. So, this the; what can I have written. So, when electron say this is the case for hydrogen atom and when electron in is in bour or width ok.

So, this is the specification and then whatever value here we have to note it down. So, based on that, we can write the state of this electron it is or energy of the that is spectra scopic time of the electron this specifically stress of the electron. So, what would it will be 2 s plus 1 plus 1 l j. So, s is half. So, it will be 2, l is 0; l is 0 for that electron.

So, it will be s s and j is half so, for this is the state for both electron now. So, this is basically this is the lowest state of the state is called down state, but it can have electron can go at higher state. So, then it will be called excited state it will be called excited state so, for excited state. So, next one is n equal to 2 right or n equal to 2 n equal to 2 ok. So, corresponding l will be 0, 1, 0, 1and corresponding s will be ok.

For that electron solve that (Refer Time: 07:52) will half ok. So, corresponding j will be l equal to 0, j is s half j is half and l equal 1 s equal to half. So, it will be half and 3 by 2. So, for this it will be half and 3 by 2 right and for other for n equal to 3 also one can find out and that that is what I was showing in last class is H alpha line n equal to 2, n equal to 3 H alpha line.

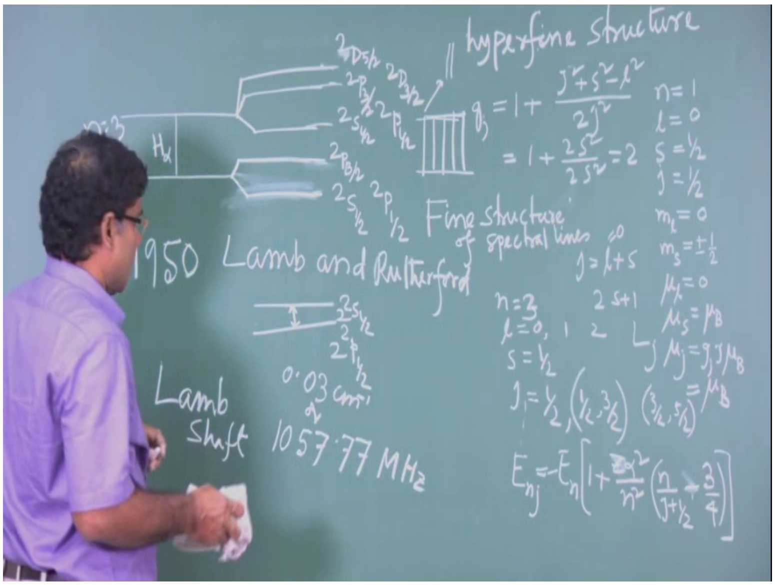
So, it is detailed into. So, n will have it will have a it will have 2 j actual half and 3 by 2 and I have shown you that energy define some energy define some E n j E n j. So, that is equal to E n say minus E n or as I discussed earlier; So, 1 plus n square z square alpha square by n square.

This n by j plus half n by j plus half minus 3 by 2 or 3 by 4 so, that is the energy depends on n and j if that is the depend on l ok. So, it will be spitted into 2 it will be spitted into 2 and it will be spitted into how many there will be 3 l, there will be 3 l 0 1 2 s half one electrons half.

So, then you will get this half 3 by 2 another set you will get for 3 we will get 3 by 2 and 5 by 2 j value for n equal to 3. So, you will have 3 j value half th it is not we say. So, value one will be this another will be this here I think this is 3 half or half it will be this for 3 by 2 it will be this and for 5 by 2 it will be this ok.

So, this states we not note that this was 2 by 2 s half 2 P half the 2 states energy is having same and then this 1 2 P 2 P half sorry 2 P 3 by 2 this 1, 2 P 3 by 2 and here again 2 n is different, but this is again s half 2 P half this is the steps and then here 2 2 or this P p 3 by 2 and then 2 d 3 by 2 d 3 by 2 here, because l equal to 2 d and then and then this 1 is for l equal to 2 and this is j equal to 5 by 2.

(Refer Slide Time: 12:26)



So, this will be 2 or l it is the d and j 5 by 2 ok. So, that was that was the splitting of the energy levels and this each energy level is now level by a spectra scopic electron. This are called the steps energy steps of the electron and here I showed you that it will be this H alpha line will get 5 condition and it will get five spectra lines.

So, now, this as I so, now, am I will now repeat? So, this I will get whatever explained to object 5 lines. So, one can get five lines. So, this is the called five structures five structures. So, actually this after including the spin angular momentum as well as the then consider the LS coupling of ln s means orbital angular momentum and spin angular momentum considering their coupling LS coupling.

So, now energy depends on j and we are able to explain the fine structure we are able to explain the fine structure of spectral line fine structure of fine structure of spectral lines of spectral lines ok. So, now, here you can notice that the energy of this two states is half and P half since the j l was same.

So, energy as same, but it was seen that under it was seen that this I think is I think it is 1950; 1950 it was seen that this energy of this two are not same basically there is a very very small change between this two levels. This two levels and this it was seen that this 2 2 s half this energy level is slightly shift it is slightly shift it is upward, then the then the 2 P half ok.

So, and this difference this difference is very small as a it is a in terms of wave number it 0.03 centimeter inverse and in terms of frequency I think in terms of frequency it is 1100 2 P of s 1057.77 or 1057.77 megahertz in terms of frequency.

This in terms of wave number this is the; this the shift of this energy level ok. So, this was discovered by Lamb and Rutherford this was discovered by Lamb and Rutherford and this effect is called Lamb shift ok. So, that was observed with very sensitive very sensitive spectrometer you can see this is a 950 or 947 during that time. So, it was in this kind of shift between this two energy level.

So, basically n equal to 2; So, this generally with the shift with the height two here in two here in 2 s of in 2 2 s P by 2 So, it is suppose to be same energy for there is a slight change of energy this s of have slightly height energy than the P half and this discovery was I think this done by Lamb and Rutherford. So, this shift is called the Lamb shift. So, later on I will try to explain, but this I do not know it may be difficult for you later on I will try to explain what is the origin of this of this Lamb shift and another effect also people found that. So, it is also observed that.

This whatever specter lines fine structure we have seen again this fine structure it is seen their fine structure again they are split it not for all, but sometimes we see their some splitting of the of the fine structure and that is, because of the influence of the nucleus because nuclear also have seen it has magnetic moment angular momentum ok. So, it is effect is very small, but there is a slight effect of this nucleus on this on this electron. So, due to that this line generally again it seen that it is spitted into say it may be double it triple it depends on the spectacular lines and atoms.

So, a nucleus of course; So, these are called again this fine structure again this shows from specter line shows more lines. So, this is called hyper fine structure this is called hyper fine structure hyper fine structure and origin of this hyper fine structure is basically that influence or interaction of nucleus with the with the electron because nucleus have angular momentum nuclear have magnetic moment.

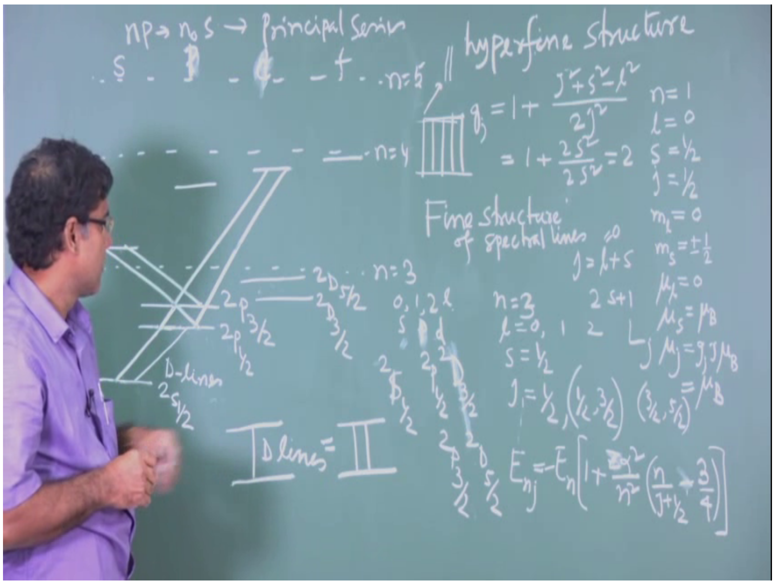
So, that is the origin of hyper fine structure. So, just here just I defined terms later on we will see how to explain them if possible if time permit we see. So, this is the fine structures which is explained from the LS coupling.

Where s was introduced and we remember that I mentioned the sodium d line sodium d line it is splitted into it is splitted into two or it is splitted into two lines sodium d 1 and d 2 lines. So, let us see whether we can explain that that sodium d 1 and d 2 lines. So, as I mention that sodium this alkali atom it is treated as a similar to hydrogen atom because in the outer most cell is one electron and effective nuclear positive charge is z minus sigma.

So, it is close to 1 it is not 11 because z value is 11 for sodium. So, it is around 2 or 3 depending on the value of sigma scheming factors any constant.

So, for sodium as I mentioned that these say.

(Refer Slide Time: 22:43)



This is n equal to 3, then let me draw here n equal to 4, because n equal to 1 in equal to 1 that are occupied. So, after most electron this is the after most electron starting for n equal to 3. So, then one can take n equal to 5 right n equal to 6 etcetera and what are the origin of this dual line. So, as I mentioned that if I divided them as a for l value n equal to 1 means l value 0, 1, 2; 0, 1, 2 l value so, s P d s P d s P d ok.

So, for lower l value for a same for a same n value; so, lowest energy will be for lowest l value ok. So, that here let me just show you this s 1 will be here, than this one will be say P and say this one will be d this one will be d. Similarly for n equal to 4 this one will be s this one will be P this one will be d and then other one will be f ok.

So, this way so; condition from as this for principal series. So, P to s that was the condition P to s principle series n P to n 0 s so, that is the principle series ok so, P to n. So, that was the condition and this line. So, that is basically this one here let me write this is s, this is P, this is d, this is f right this f. So, this condition sodium D-lines so, that we have seen and seen, but these D-lines is basically is two lines is not one line is that two line is that two line is that two line double it has double a structure.

So, that whether considering this energy level j; whether we can explain or not; so, it seems hydrogen like atom it is the hydrogen it is a it is a like hydrogen atom. So, here one can consider this similar way one can find out l s j, because this is one electron is participating in transition. So, here so, what will be this for n equal to 3 this is the l value.

So, what will be the spectro scopic term; spectro scopic term for l equal to 0 it will be s equal to always half for one electron.

So, it will be 2 2 s l equal to 0, 2 s and j equal to half now for l equal to 1 it will be 2 P half and 2 P 3 by 2 ok. Now l equal to 2 that is d. So, for depth we have to find out. So, from here I can see for n equal to 3 whatever this level I can write this is 2 s half 2 s half l equal to 0, l equal to 0 s orbit 2 and half and this is l equal to 1 this is l equal to 1.

So, it is it is sorry I think it will be P it will be d ok. So, now, this l equal to 0, l equal to 0 is this l equal to 1 this is; now it is splitted into two lines now you see j is half and j is 3 by 2. So, j value is different. So, this will be splitted into is not one line this is spllited into two line. So, this will be lower energy 2 P half and this will be 2 P 3 by 2 2 P 3 by 2 hm. So, transition transition is restricted by del l equal to plus minus 1.

So, it is P 2 yes it is always permissible. So, so this level to this it is possible allowed and now it is basically another transition is allowed from P 3 half to s half ok. So, now, this because of this splitting of this the yeah P orbital's splitted into two now P orbital's splitted into two now, because their j value different. So, now, it is it will have two condition. So, earlier whatever for sodium case as I told D-lines.

Now, it is basically is not two lines it is it is its not one line it is two line ok. So, this are double a structure and if you notice in this case also l equal to l equal to 2. So, here what will get you will get of s value that is pin is half. So, you will get d I think d 2 d 3 by 2 and 2 d 5 by 2 ok. Now if you consider this line. So, this is for d fine now d have again it is not it is it is splitted into two splitted it is splitted into two; this one and this another one is this. So, let me draw here let me draw here. So, this will be 2 d 3 by 2 and this 2 d 5 by 2 5 by 2 ok. Now, that is transition from d to P is allowed d to is allowed or s to for sharp serious that was s to P is allowed.

So, again s to P you will see is it a one transition there will be two transition here ok. So, for sharp series for principle series for defuse series defuse series is for are from n d to n P n d to n p; So, from n d to n p. So, from d to P d to P now you see it upon it is it is it is 2. So, basically whatever in sodium spectra whatever series you have got without considering the spin and this LS interaction total without considering the total j value. So, we have we have seen that what about single lines each line is double it each line is consist of two lines and it is called double a structures.

So, sodium spectra lines have double a structure the spacing is minimal here in this case this since we are familiar with this one, because this is very bright yellow light and in laboratory this spectral lines is used for different study of different purpose, but other lines also have it is not single line it is the two lines ok. So, this is called double structure so.

So, now, here also see this alkali atom spectra or alkali atom or double structure of the alkali spectra, that is; now is explained from this j value considering the j or l s coupling ok. So, now, it is this is also called fine structure is called also fine structure ok. So, this fine structure also we are able to explain.

So, now, I will stop here. So, in case of (Refer Time: 33:00) energy effect one can show using this total angular momentum one can explain (Refer Time: 33:16) given effect; so, that I will show you in next class.

Thank you.