Fundamentals of Spectroscopy
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Lecture 45
Resonance Spectroscopy - Introduction 1

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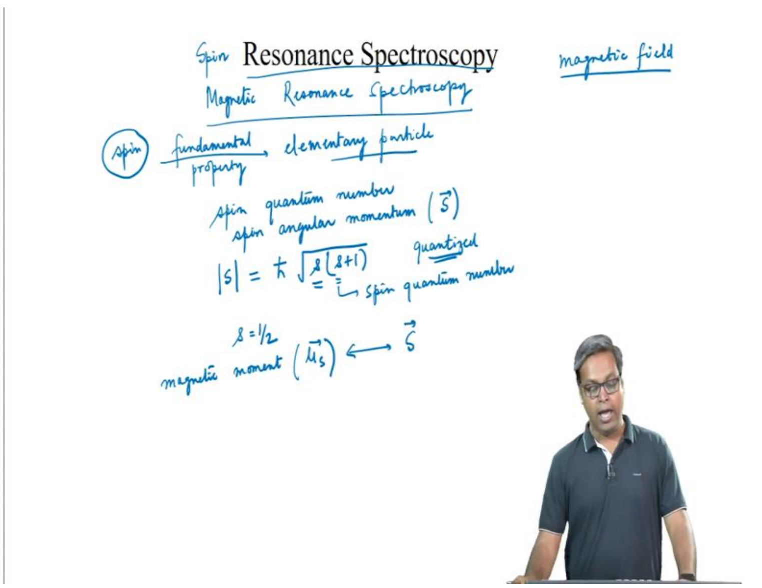

Hello, welcome to the lecture. In today's lecture, we will start a new module on Resonance spectroscopy. So, it can be Spin Resonance spectroscopy or Magnetic Resonance spectroscopy. This Spectroscopy differs from most other kinds of the Spectroscopy. Here, the light matter interaction involves the magnetic field, so, the matter interacts with the magnetic field of light and not the electric field of light. The magnetic field is used to provide the energy level separations probed by the radiation.

So, both the Spectroscopy involves spin. So, spin is a fundamental property of an elementary particle. So it is a fundamental property of any elementary particle. So, for example electron is an elementary particle and electron has spin. So, this spin has no classical analogue. So, the introduction of spin quantum number, in quantum mechanics could explain many puzzling features. So, the spin is manifested but the presence of an intrinsic angular momentum.

So, in this case, is the spin angular momentum which is represented by S and the spin angular momentum is a vector. A convenient formalism is that Spin angular momentum arises from the rotation of electrons around its Axis and the magnitude of this spin angular momentum, which is given by modulus of is S is h cross root over s times s + 1. So here, this small s represents spin quantum number. This means the angular momentum of the spin angular momentum is quantized.

So for an electron the value of the spin quantum number that is S equal half. So, Electron being a charge particle it has something known as magnetic moment which is denoted by Mu s which is vector and this magnetic moment Mu s is associated with the spin angular momentum capital S.

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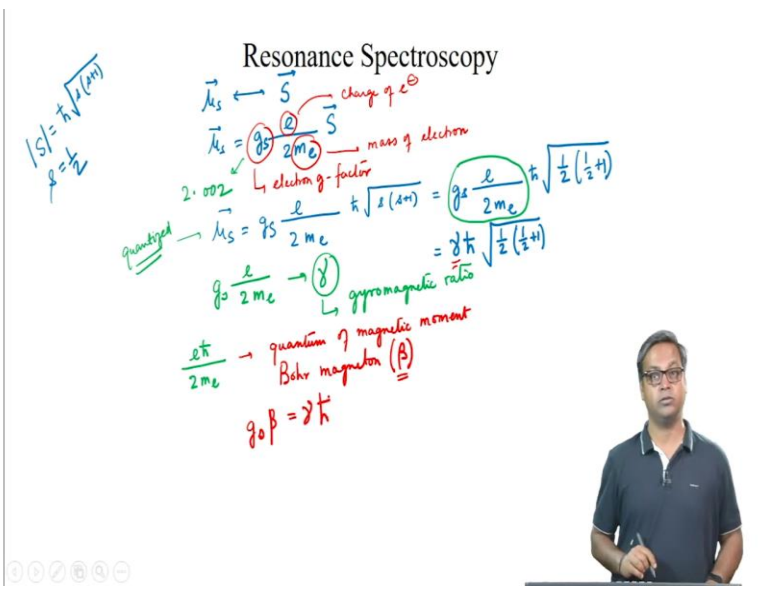

And the relation between this Mu s and this spin angular momentum is given by Mu s = g of s e by 2m e when the screen angular momentum social the g s is electron g factor and this small e is the charge of electron and m e is the mass of election so we can write Mu s equals to g s by 2 me and because s = h cross root over s times s + 1 so we can write h cross root over s tines s + 1 and now s equals to half. So, we can further write this as gs e by 2m e root over 1/2 times 1/2 + 1. So, we can write now that this equals h cross root over 1/2 times 1/2+1.

And the value of this electron g factor that is g s is 2.002 so we wrote gs e by 2m e so gs e by 2m e this we wrote as gamma and gamma is known as the shadow magnetic ratio. So, we can see that this Mu s is also quantized and the quantity that e h cross divided by 2m e is known as the Quantum of magnetic moment and it is also known as Bohr Magneton which is denoted by beta. So by comparing the two expressions in which we have beta and gamma we can write gs beta = gamma h cross. So before proceeding further, let us study the general properties of angular momentum.

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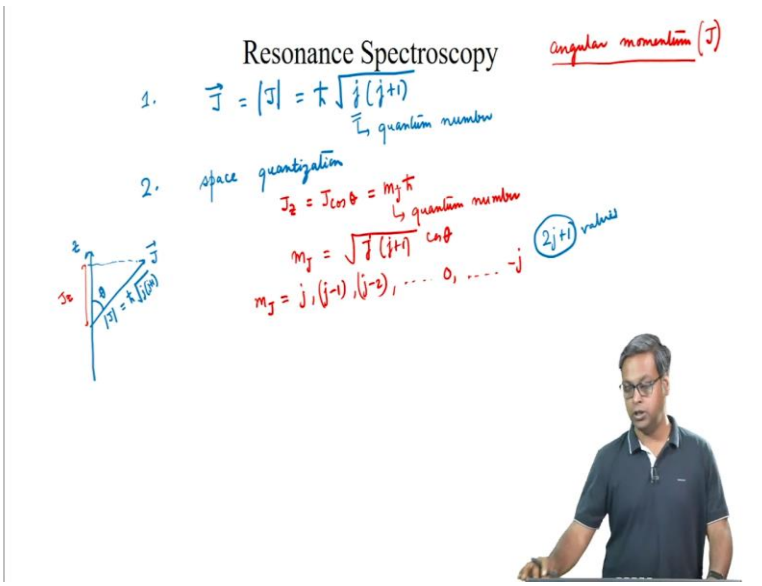

So, show the angular momentum is in general denoted by J. So let us study the general properties of angular momentum in quantum mechanics. So, the first property is and we saw this during our discussion on this spin angular momentum just like couple of days back, the angular momentum vector that is the vector J has a magnitude which is given by so, the magnitude of is given by h cross Root over j times j+1 where the small j is a Quantum number which is the angular momentum quantum number.

That means it is a quantum number characterizing angular momentum. So, secondly, there are only certain possible orientations of the vector that is affected j with respect to Z axis. This is known as Space Quantization. So, let us say, if the vector J this is our Z-axis let us say vector J makes an angle theta with the z-axis. So this is our vector J and the magnitude of J equals h cross root over j times j+1. So, the possible values of theta will be such that the Z component of J, Z component of J which we can denote by this link.

That is the projection of J on the Z axis which we can call J Z will also be quantized. So, we can write J Z equals J cos theta and because it is quantized it is mj h cross. So, this m j is the Quantum number. So, we can write that m j = Root over j times j+1 quantized. So, we have seen this during a discussion on angular momentum in rotational Spectroscopy. So, from this relation, it follows that that m j quantum number can have the following values.

It can have values of like m j can be the can take the values of j, j-1, j-2 dot dot dot dot 0 is another value and it will go up to -j. So, in total there can be 2j + 1 value of m j particle with angular momentum of j and magnetic moment m j.

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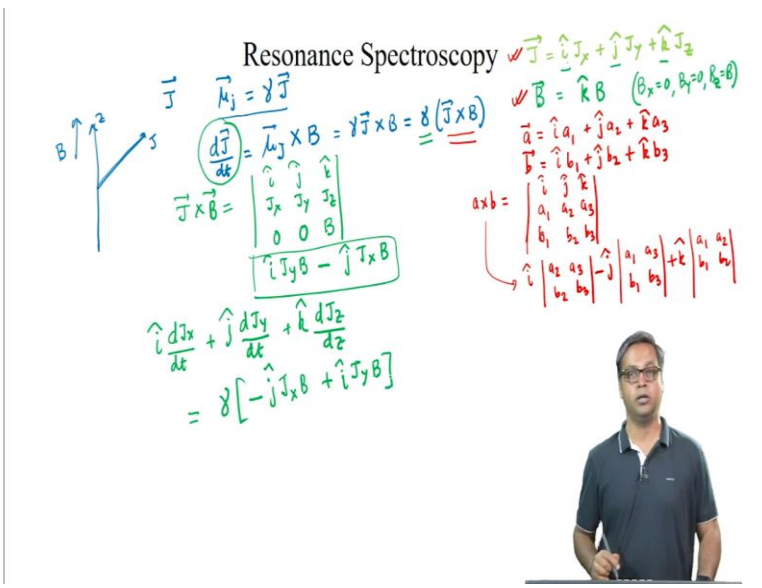

So, the particle has angular momentum of J and magnetic moment Mu j, so mu j is given by Gama diamagnetic ratio x j. So, when this particle is placed in a magnetic field applied in the Z direction, then, for an orientation of J, so let us say this is my Z direction and the magnetic field is applied in the Z direction. And our J is in this direction. So, then, for an orientation of j which is this export x on the magnet which is given by dJ by dt which is given by Mu j cross B and because Mu j is given by gamma J, we can write this gamma J cross B or gamma J cross B.

So, the vector J written in terms of its Cartesian coordinates. So, we can write, vector J written as i hat Jx + j hat J y + k hat J z. So, this i, j and k, this i, j and k are the 3 unit vectors along X Y and Z. And for the magnetic field because B is applied along the Z Axis we have we can write B = k hat B. This is because it is only along the Z axis So BX = 0, B Y = 0 and BZ = B. So now let us look into what do you mean by cross products. Let us say we have two vectors: one is a and vector a is given by i hat a1+ j hat a2 + k hat a3 and you have another vector that is b which is given by i hat b1 + j hat b2 + j hat b3.

So now if you need to compute, it is a cross b. So that a cross b this a cross b so that we have to write as i, j, k then a1, a2, a3, b1, b2, b3. So, this is a cross b will be I have to write i then, a2 a3 b2 b3 - j a1 a3 b1 b3 +k a1 a2 b1 b2. So, now we have to compute a cross b. And this is vector J and this is vector V. So, if you compute this j cross b what we get is so we can write i j k this is jx jy jz but for b this i and j component is 0. We only have b here. So, this will be equal to what we will get this i times J y B - J times J x B.

So, we can write that i because j equals i Jx +i Jy + i Jz so this dJ dt we can write as i dJx dt + j dJy dt + k dJz dt and it will be the same thing that have computed but only multiplied by b, so we can write this as gamma – j times J x B + i times J y B.

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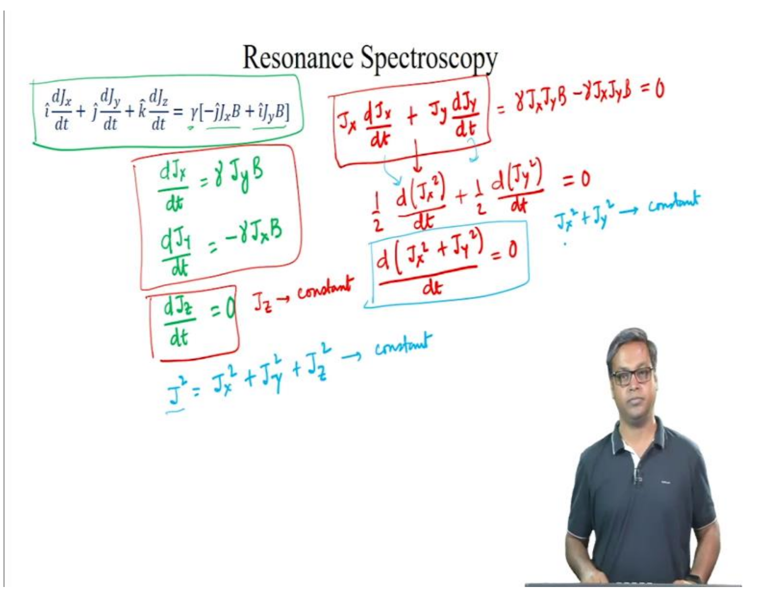

So we have this expression I dJs dt + J dJy dt + K dJz by dt equals gamma - j JxB + i JyB. So, if you compare the expression we get dJ x dt = Gamma JyB and dJy dt = -gamma JxB and also we can see that d Jz dt = 0. So this that is dJz dt is 0, indicates that Jz is a constant. That means Jz is concerned but Jx and Jy depends on i? So, using these two expressions we can write that J x dJ x dt + Jy dJy dt so dJ dt will be gamma Jx Jy B - Gamma Jx Jy B so that will be equal to 0. So, because Jx dJx dt + Jy dJy dt is 0, we can further write as 1/2 d of Jx square dt.

Because if we have x square then take the derivative is 2Jx now we are divided by half so we can write this term as 1/2 dJx square dt and this as + 1/2 d Jy square by dt = 0. Or in other words what we get is, d of Jx squared + Jy squared dt equals 0. So this expression d of Jx squared + Jy squared dt = 0 tells us that Jx squared + Jy squared is a constant. Hence because we have Jz square which is a constant and x squared + y squared is also a constant.

So, we can write J squared which is nothing but Jx squared + Jy squared + Jz squared so this is a constant. That is when in a external magnetic field the J square and J z are constants of motion but Jx and Jy can change with time. So, we will end this lecture here. In the next lecture, we will discuss the consequences of what we have learnt today because of this J square and J z constant.