Organic Photochemistry and Pericyclic Reactions

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Lecture No. #01
Introduction to Organic Photochemistry

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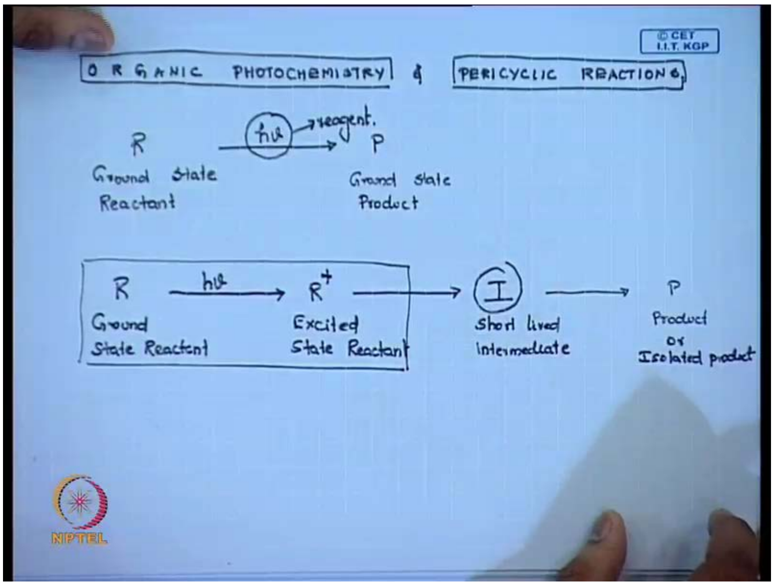

Yeah, so the course title which we are going to deal with this semester is organic photochemistry, and pericyclic reactions. (No audio from 00:37 to 00:47) So, till next semester, we will be trying to concentrate on the first part that is your organic photo chemistry and after next semester, we will be trying to discuss about the pericyclic reactions.

Today class, I will just try to introduce you to organic photochemistry. (No audio from 01:17 to 01:25) So, what organic photochemistry is basically, it is nothing but it tells you about the interaction of life with organic material.

So, what happens in in brief, when a light interacts with your ground state reactant R, it tries to undergo different types of transformation to give you the product P. The basic or the simplest representation of organic photo chemistry can be written like this; you have an R, which we call them as a ground state reactant, you shine with light h nu, which we call as a photon; this R now undergoes different sort of transformation to give you the product P, we call that as a ground state product. So, this is the simplest representation of an organic photochemistry.

You guys know about organic chemical reactions, same way you have an R, you put some reagent, then your R get transformed into your P. In organic photochemistry your reagent is nothing but it is your h nu.

Now, what we will try to do is now briefly understand. How this R is getting transformed into P? That is a broad spectrum of looking into organic photochemistry. You take a ground state reactant as a earlier mentioned, you shine light on it, what happens? You have a ground state reactant, once the light shines on this reactant, this reactant now transforms from its, if you consider a lower energy is 0, from its ground state energy to an excited state energy right. This most of the time these transitions are electronic transitions. So your R, once it interacts with the light, it becomes excited state reactants which will call as R star.

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So, your R is not getting converted into your excited state reactant. The point is here should be noted, is that your R star is not going to give you the product P. See, this R star will not give you the final ground state product P or in other words, is not going to give you the isolated product.

So, what this R star does now in the excited state, it does an electron transfer, or it can do an atom transfer, or it can break the bond, or it can make a mould, to give you an intermediate I. The intermediate I can be a ground state species, but it is a very short lived species, so that this intermediate gets transformed immediately to give you the product P.

So, what we say that, R star gives you a short lived intermediate. The short lived intermediate can be like carbide, or it can be a nitride, diradicals, so, which can react very fast to give you the products P.

See this is a ground state product, or you can call them as isolated product, you can isolate this guys. See the point is that, the I, that also is a ground state species, that also is a ground state product, but only the thing is that I is highly reactive that it immediately gets transformed to your P. So, this is the broader outlook of your organic photochemistry.

So you, if you just review back, you have a ground state reactant, which interacts with your light, gets excited to its excited state, which you call as R star, and this excited state reactant, then does an atom transfer or electron transfer, bond breaking or bond making, to give you the short lived intermediate like carbide, nitride or diradicals, and this short lived intermediate can give you the final product P. It is clear.

Now, what we will do is that, we will take each of this steps like R to R star, and getting to detail then we will try to understand, how R star gets to I, and finally I to p.

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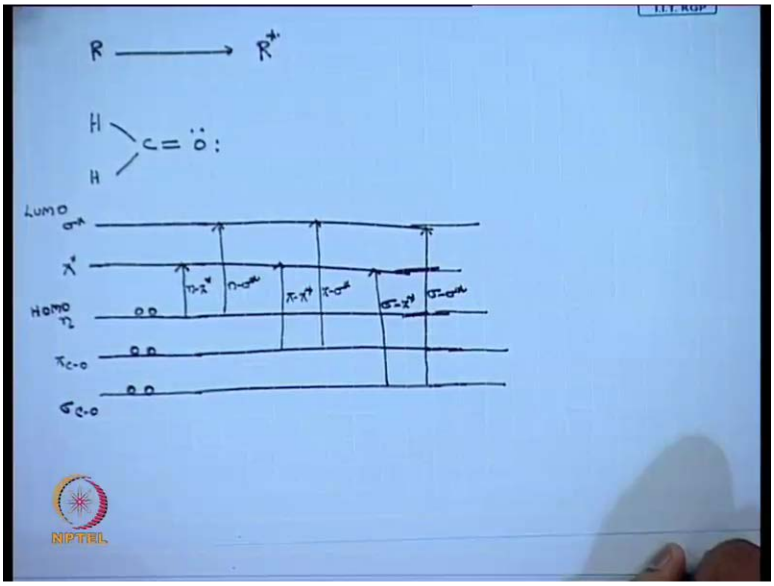

So, we will start, to understand, this step first, that is R to R star. To understand this part, that is R to R star, we will take a simplest molecule in the ground state level like well characterized and simplest molecule. For example, formaldehyde.

So, now you have formaldehyde molecule, if I shine light on this formaldehyde molecule what happens? See I am not going to give you any select, like any selection. I am just saying that, you have a formaldehyde molecule, you are going to shine light on this. So, what are the possible transitions, that means, all the transitions which this formaldehyde can do. Just we will write down, write that part alone. All the transitions, you are going to ignore any transitions.

So, you have a sigma, you all write the homo of that first, sigma C O, then you have a pi, then you have a non bondage electrons, so you have a, this we will consider as the homo. Then, we will write a sequent steps, then lumo of this. Now, we will see that, once the light comes, what are the transitions you are going to see.

We will start from n. So, the first transition you can think about is, n pi star. Next, we can see, n sigma star transition. So, from non bondage we can see this both the transition, n pi star as well as n sigma star. So, I am doing all the transition, all the possible right.

Then, we can have a from pi, we will have a pi-pi star transition and then, we will have a pi-sigma star transition from sigma, we can have a sigma-pi star transition then you have a sigma-sigma star transition.

So, if you take a formaldehyde and shine light, you can see 6 type of transitions, from non bonded you can see two transitions, from your pi 2 and your sigma 2 transitions. That is good.

Now, I am slowly going to put some criteria's in this transitions. I am going to say that, see guys, I am going to give you very minimum amount of energy. I am not going to tell the number, just for crude, very minimum amount of energy, I am going to shine on this formaldehyde. So, what transition we can observe, then the minimum energy with that what transition we can, it can happen, your n pi star transition right. Other transition needs more energy.

So, with the minimum amount of energy I can do my n pi star transition. So, shall we take that we can put that selection and take this n pi star transition out. So, putting a selection I am going to a possible transition for that particular selection, that is, n pi star transition.

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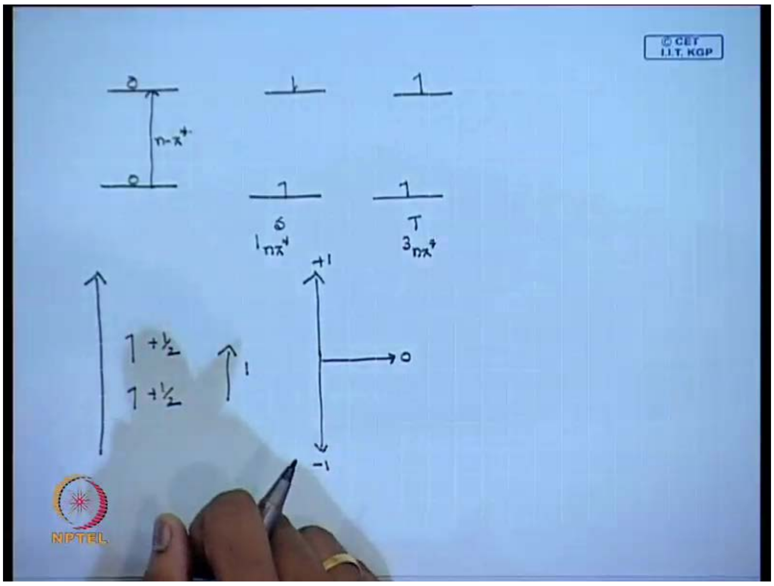

So, something I am missing in this transition, while writing this electrons what I am missing on? anything from you. While writing this electron I am missing something, spin very good. So, shall we introduce now the spin into this. See first I am introducing a small concept called selection of small energy. I am just picking out my n pi star transition. Now, I am introducing one more concept called spin right.

So, I can write spin in two ways. One it can be this direction your spin, or it can be in this direction right. One can be parallel, another can be anti parallel. So, we call this parallel spin as triplet, and we call this anti parallel spin as singlet.

Is not because of that exactly with why we call them as singlet and triplet. Why we call this as a triplet? For example, you take this triplet state, consider this triplet state, for one spin we can write plus half I am taking the triplet, for another spin I am writing plus half. So, in the presence of a magnetic field, what happens? This two spin can combine to give you a new spin is can be one, right. The new spin will be formed.

Now, what happens, this spin can align three ways with the magnetic field. One, it can align with the direction of the magnetic field, which you call as plus 1, or it can align opposite to your magnetic field, which you call as minus 1, or it will be a right angle to your magnetic field, call as 0.

So, now you have three states. That is why, we call them as a triplet, clear. Why we call them as a singlet, triplet. Yeah for general view we say that, if it is a parallel spin, then you say, it is like triplet and if it is a anti parallel spin we say, this is singlet, but actually speaking it is like this.

How to represent now, a n star pi star singlet state? The best way of this, is singlet n pi star, this you write as triplet n pi star. That is how we represent singlet, if it is a sing let pi pi star, then you write singlet pi pi star transition and triplet pi pi star transition. Clear, up to this is clear.

So, we have now introduced a concept of spin into this, and we are saying that, singlet and triplet. Now, what I am going to do? I am going to introduce one more concept here is energy. First, I have introduce a concept of spin. Now, I am going to introduce a concept of energy.

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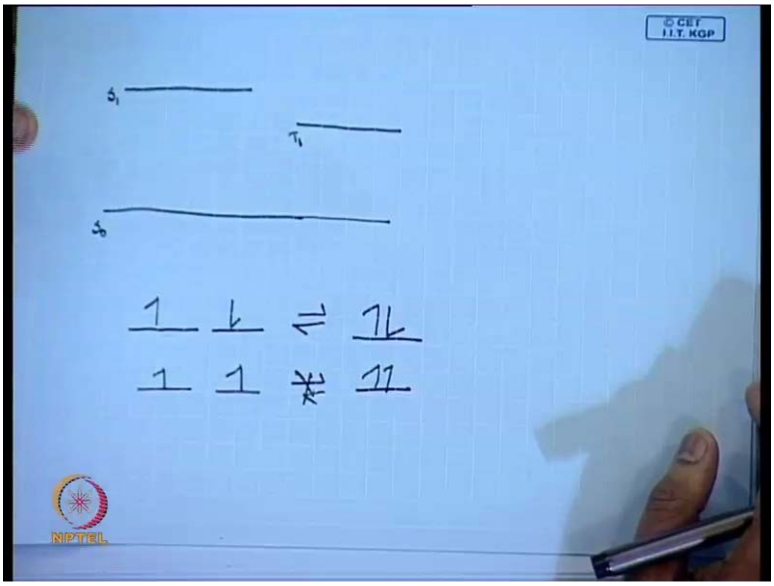

So, if I introduce a concept of energy, I say this is s 0, which has a ground state energy. Then, I will write my s 1, which is your excited state energy. You can now place your triplet, as team. You can place either above singlet based on the energy level, or you can place equal to your singlet, or you can place below the singlet, right. So, I am going to place that below the singlet, fine.

So, now we will see why, I am placing this triplet below my singlet. That means, the energy of triplet is lesser than singlet, why I am doing so? Any idea? Why I place my triplet below my singlet? Anyone? Is nothing but, what you studied in your hund’s rule ? What your hund’s rule says that?

See, if you have a singlet, this always try to come together, right. Two orbital’s with an anti parallel, you always try to come together, and once they come together, they repel away. They come together and they repel. They do not like to be together, because they repel.

But if you draw triplet, this chance is not possible at all. Because, they never like to come together, they stay cleanly away from them. And they saying that, there is no repulsion I am happy. So, I will be always the lower energy.

See, singlet you have a sort of maximum repulsion, you have an habit to coming together and repelling away from each other. That is why, your singlet has much higher energy compared to the triplet. So, that is why, I put my s 0 here, s 1 and T 1, clear.

(No audio from 18:10 to 18:40).

Now, we will take formaldehyde, and see that n pi star transition. We try to put all the information, what we understood now? So, if I take my formaldehyde molecule, and pass light, shine light with minimum energy.

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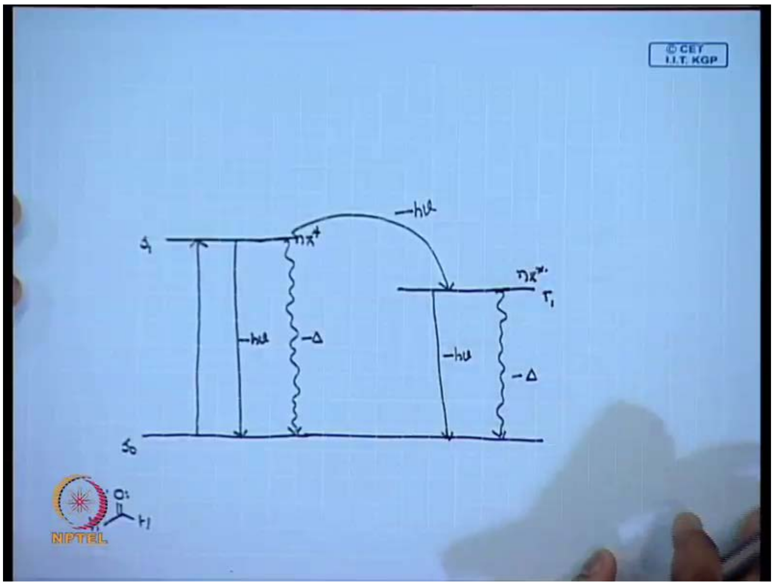

So, I can write, my s 0 and s 1, T 1, this is n pi star transition. Figure top, write on the top that is also not a big problem s 1, n pi star transition. So you have s 0 to s 1.

So you have, once the light shines, you have your non bonded electron going to your pi star, n pi star transition takes place. Now, what this molecule do? Does in s 1. Just generally speaking, what it can do? When it is in s 1.

It can come down in two ways. One, it can come down giving out the light, or it can come down by giving out you the heat, right. This two way it can try to do. Once it comes down, by giving out light, you call that as a fluorescent process, which we know, we will get into that, little bit later, or other thing, what you can do? Yeah it can come down to his s 0 state, or what it can do? It can do a non diluted process. This is, how it can come to s 0? If does not like to do, it does not want to come to s 0, what it can do? It can go to T 1, that process, it can go by giving out the light, right. From T 1, then it can come back to a s 0, same way it can give the light out, or it can give a. So, it can do this sort of transient when it goes from R to R star it has have an option of doing this.

Later on, we will see, why, when it has to do, to photo physical that is s 0, or when it has to undergo an inter system crossing to give triplet. We will to try to understand that conditions, later on. Now, just we will try to understand the process, then we have a lot of things, which we have to say, why it has to go to s 0, or which part it tries to take.

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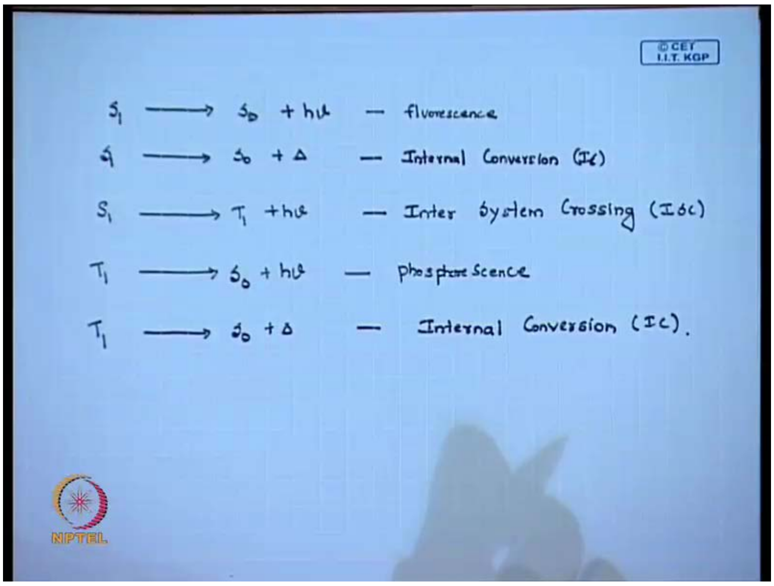

$S_1 \longrightarrow S_0 + h\nu$ — fluorescence

$S_1 \longrightarrow S_0 + \Delta$ — Internal Conversion (IC)

$S_1 \longrightarrow T_1 + h\nu$ — Inter System Crossing (ISC)

$T_1 \longrightarrow S_0 + h\nu$ — phosphorescence

$T_1 \longrightarrow S_0 + \Delta$ — Internal Conversion (IC).

Will, now, slowly label this each process . If it goes from s 1 to s 0, giving out light, you call this as fluorescence, right. If it goes from s 1 to s 0, by giving out heat, you call this as internal conversion, which you call as I C. If it goes from s 1 to T 1, giving out light, this you call as inter system crossing. Then if you have T 1 to s 0 plus, we call this as phosphorescence, very good. Again you can call this as, internal conversion. So it can do, this type of all the thing, that is clear.

Now what will try to, see, if you try to understand this process. For example, with respect to number, you will be knowing much better. For example, if I ask, like which process will be faster, whether it is fluorescent, or it will be a phosphorescence. Yeah phosphorescence, because it has to flip is spin, because it is coming from a triplet to singlet.

So, knowing that with respect to number will tell you more. So, we will see the same process, with respect to number. We will put the numbers on the transition, so that, we get an idea about it.

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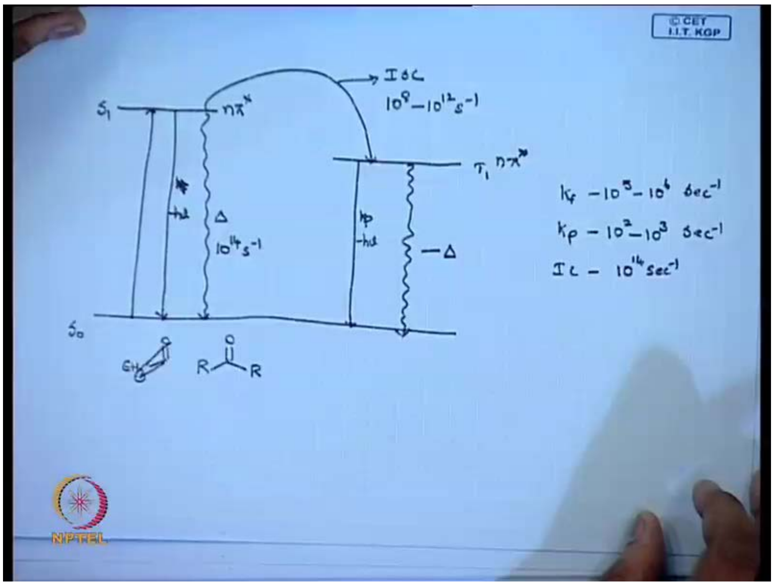

See for fluorescence, or we can write it in a separate page. So that you can, because it does not work for formaldehyde, it works for general ketones ,this numbers. If I take an for example, R for a general ketone is 0 when I have an s 1 and my T 1 talking of n pi star. So, let take for a ketone and trying to understand how this thing.

See, for fluorescent, the rate constant for fluorescent k f, that will be 10 to the power of 5, to 10 to the power of 6 second inverse, see how fast the process is? It goes s 0 to s 1, but from s 1 to s 0, it does not need any spin flipping, right. So, it comes down so fast. So, it takes only 10 to the power of 5 to 10 to the power of 6 second inverse, clear.

Now, we will just compare that, with phosphoresce and see how much time it takes. If you take for k p that this process, the rate constant for phosphoresce, where it is, it has to flip its spin, right. It has to come from triplet to ground state singlet. Any idea? How much, whether it will be a fast process or slow process? It should be a slow process, this numbers, because we are have this vague number 10 to the power of 5, we cannot remember, how slow it can be? Yes, very good. So it will be from 10 to the power of 2 to 10 to the power of 3 second inverse. See, how much it gets delayed. Yeah, its gets delayed so much, Fine.

I am then we can see this process, which is your internal conversion, how fast it can be? It can be faster than your fluorescence, or slower than a fluorescence, internal conversion, where it just radiates the heat, that is all. It should be faster or slower? Slower, just it has to radiate the heat, that is all it has to do. Slower ,are you sure? It does like 10 to the power of 14 second inverse.

So, your I C is 10 to the power of 14 second inverse, thus that job so fast. See, that is why, I said that this number has lot of meaning. It is not that knowing the process, it say that s going from s 1 to s 0 s it is florescence, going from T 1 to s 0 it is phosphoresce, that is fine, but understanding with respect to number tells you, how which process is faster, which is a very delayed process all this things.

Then they will just get and in detail ,and try to understand why this process are slower and faster. First, we will see the numbers, any idea about this, I S C? What number this can be, this intersystem crossing, second as spin flipping process, right, but normally you know how this goes, s 1 to T 1 it will not jump like that. How it does? You have any idea, times, it will be slower than I C, whether it will be slower than your phosphoresce. No, it whether the process I S C will be slower than phosphoresce, or it will be faster than phosphorescence. Because, both are spin flipping process, it should be faster. So, it does like 10 to the power of 8 to 10 to the power of 12 second inverse.

That is why, because the energy gap between the singlet and triplet is, sometimes are very small, not compared to your T 1 to s 0. T 1 to s 0, the energy gap is huge, but s 1 to T 1, the energy gap most of the time will be small. That is why, the process, even it does a spin flipping, it does fast. So, you get a rough idea now, right. How this all process having the numbers. That is good. Any now, doubt on this?

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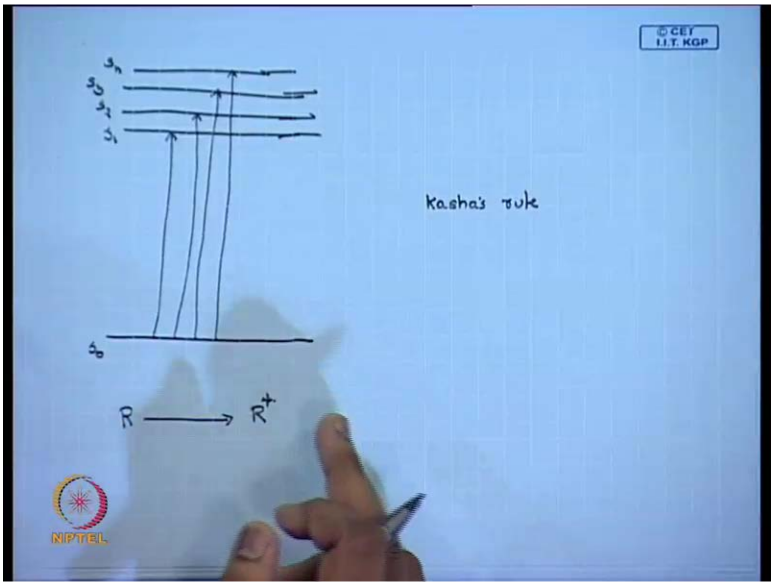

Now, we will same transition, I will ask you like s 0, you write s 0 right, and you say that, you write only, most of the time you try to write only s 1. See, there are other levels also there are right s 2 that can be s 3, you can write up to s n. Now, all this transitions, all the energy levels available there, but all the time we try to push from s 0 to s 1, and then we talk all the chemistry or physics, photo physics or photochemistry. We never worry about s 2 or s 3.

See, if you have a transition, I can say, it can go to s 0 to s 1, or it can go to s 2, it can go to s 3, or it can keep on going. So, that that all is allowed right. So, it happens only from s 1, any idea why?

What is that famous rule? What we can say is that, it vibrational relaxation is so fast. This all states collides immediately and collapse into s 1 state. The vibration relaxation is so fast, it just collapse and they all fall it to the s 1 state. That is why, we most of the time, we do not consider s 2, s 3, s 4, but there are some molecules, where you can see from s 2, s 3, s 4 states. What are they?

Some molecules which can do came photo physics from s 2, s 3 asolins. If you have asolin type of molecule, then it all happens from s 2, s 3 also, but most of the general molecules, which you have going to consider, most of the time, the transition tries to happen from s 1. So that is rule is called as kasha's rule.

We call this as a kasha's rule, what he says that, your fluorescent will be completely independent of the excited state. That means, your fluorescent occurs only from the s 1 state, it is completely independent of your excited state. It will all the time, it will try to occur from your s 1 state only. That is called a famous kasha's rule.

Because, your s 3, s 2 all if you see, the process will be very fast. It will be greater than your 10 to the power of 14, you cannot even see them. They all will, vibrational they collapse and they get to s 1. That is why, a all the florescence, we try to talk from only the s 1 state, clear. This we call as kasha's rule.

Your florescence is independent of your excited state, it occurs most of the time from your first singlet excited state (no audio from 33:28 to 34:02).

Now, what will try, so we were trying to understand this process R to R star. That is what, we took the first step, we said, we will try to understand this first step in detail. So, how we started we took, we took a simplest photo chemistry scheme, then we slowly moved down, we said it is an R, which gives you e interacting with h nu. That is your simplest photochemistry representation

Then, we went little bit down, and made a broader outlook. We said that R, gets excited to your R star, then gives you a short lived intermediate I, which then gives you a product P.

After that what we have said, we will take each step and try to understand in detail. So, we took R to R star initially, then we said that it can undergo a transition, all the possible transition, then I brought a some sort of criteria, and said that I will give you a minimum energy. Then we took a smallest transition n pi star, when we did n pi star, we included the concept of spin, we introduced singlet and triplet, then slowly we introduce the energy concept and we said as singlet as well as triplet. Triplet comes down and singlet will be in the higher energy generally.

There are some cases where it is reverse also. And then we summarized everything, by using a type of Jablonski diagram, and we studied kasha's rule.

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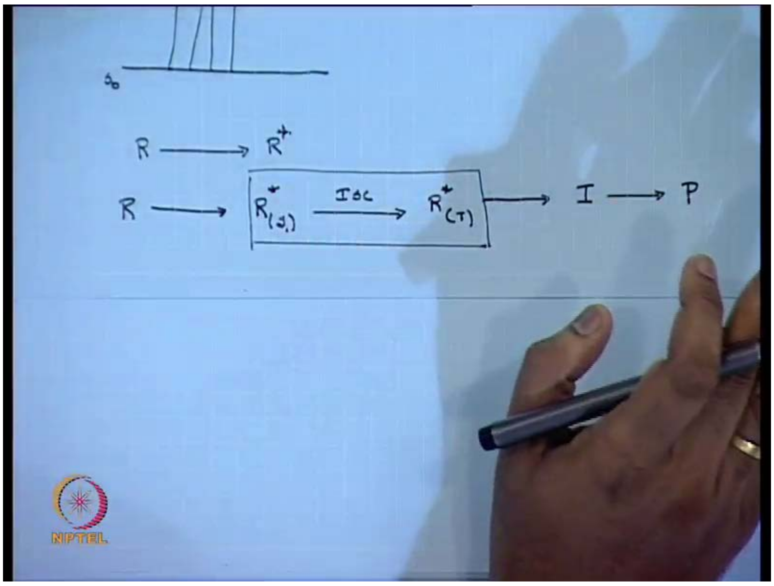

So, from R to R star, can I write like this now. I get my R, I get my R star, which will be my singlet, right. So, s 1 and then it undergoes a intersystem crossing, to give me my R star triplet, and this will give me the I and which give me the P.

See, so I have just now expanded that schematic representation. See, we have to take, this part now. In the next class, what we will do? Will try to understand in detail. How this R star to S to R star to t happens, like just by orbital structure will see, how this transition occurs. It is just a few minutes, we will discuss on that. Once we discuss, then we will move from R star to I. We will try to understand, how R star gets transformed into I and finally, we will try to understand, how I moves to P. Once we next two hour class, we will finish the introduction part. So, this will be the introduction of organic photochemistry, then we will slowly get into our reactions, it's clear.

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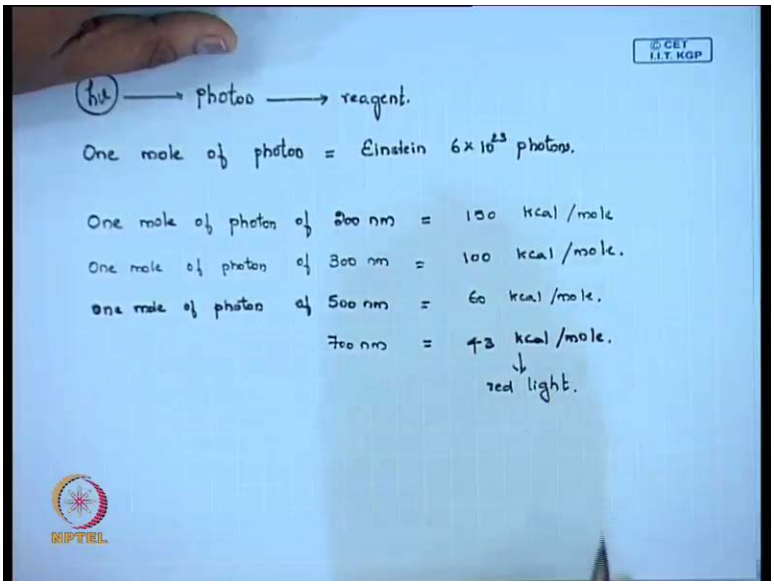

$h\nu \longrightarrow$ photon $\longrightarrow$ reagent.

One mole of photon = Einstein 6×10^{23} photons.

One mole of photon of 200 nm = 150 kcal /mole

One mole of photon of 300 nm = 100 kcal /mole.

One mole of photon of 500 nm = 60 kcal /mole.

700 nm = 43 kcal /mole.

$\downarrow$

red light.

So, what happens is that, normally if you do a chemical reaction. If you take a reagent, what you doing? One mole, you always say that it is one mole of reactant, and one mole of reagent, I am adding in to get my product.

Same like that, we also can communicate for photon also. We say one mole of photon equal to we can call them as Einstein, that is 6 into 10 to the power of 23 photons, this we call as one mole of photon. Why we should know this? Because, this will tell us the energy which we need to carry out our photochemical reaction.

For example, if I take one mole of photon of 200 nanometer. So, I am taking a light, whose wavelength is 200 nanometer. So, I am taking one mole of photon of 200 nanometer. So, how much of energy this is going to give you. You can easily calculate, because you know the formula e is equal to h nu with that, you can calculate and it comes normally 150 kilo calories per mole.

If I want to carry out some reactions, which needs an energy to break a bond of 150 kilo calories per mole. Then, I will think of doing my chemistry in 200 nanometer, that is one mole of photon of 200 nano meter will give me 150 kilo calories per mole, that much of energy I will get. That is good.

So, same way if I use, one mole of photon of 300 nanometer. Just think, if I am going to use a wavelength of light of 300 nanometer. Then, how much energy I should get, and we know that as a wavelength increases, what happens to your energy in other hand, it will decrease. So, one mole of photon of 300 nanometer will subsequently will give me 100 kilocalories per mole. Is a good number to remember. So, you have a 300 nanometer, you have 150 kilocalories, if I decrease by 300, that is 100 nanometer down, I am decreasing my energy by 50 kilocalories, which is nice.

Now, same way if I go to 500 nanometer. For example, I see that, how much is one mole of photon of 500 nanometer corresponds, then you can say it is 60 kilocalories per mole. See, most of your organic chemistry reactions happens up to this region like 500 nanometer, most of your organic reaction chemical reaction, most of you transition, electronic transition like n pi star, pi pi star, all this transitions will come around 500 nanometer value, you can do the chemistry. Because, if you see the energy it is only about 60 kilocalories per mole.

If I go down, that is like, still down of 700 nanometer. Then, you can see the energy gets subsequently very low and become like 43 kilocalories per mole. We can just do some excitation here, that is all. You do not see big chemistry happening like bond breaking, bond making, like that. See, I am talking about general things, there are exception case, but I am talking about generally what happens. This 43 kilocalories per mole, we called this as red light. That is good.

If you want to still further, move down and see like, how much nanometer, like if for example, if I take 10000 nanometer, what will happen in this? You do not get your possible electronic transition which are talking about.

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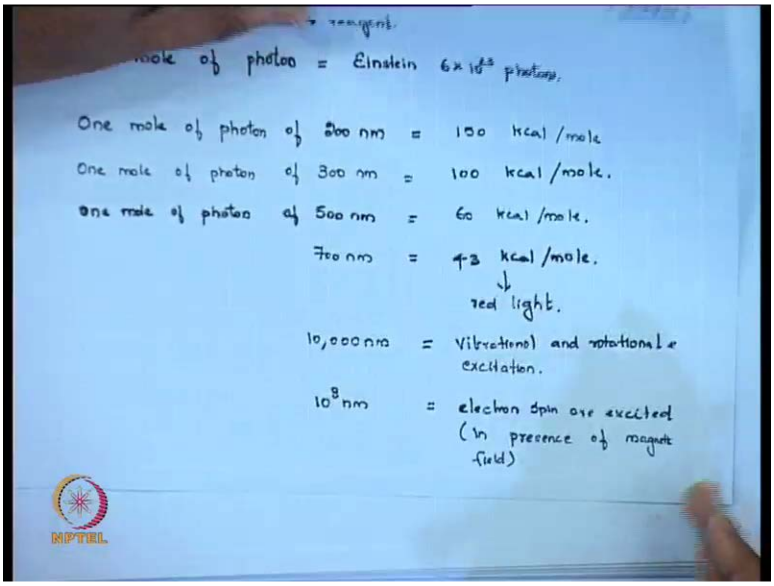

→ reagent.

mole of photon = Einstein 6×10^{23} photons.

One mole of photon of 200 nm = 150 kcal / mole

One mole of photon of 300 nm = 100 kcal / mole.

One mole of photon of 500 nm = 60 kcal / mole.

700 nm = 43 kcal / mole.

↓ red light.

10,000 nm = Vibrational and rotational excitation.

10^8 nm = electron spin are excited (in presence of magnetic field)

So, what you going to expect in this region. You going to just expand vibrational and rotational excitations, this are going to happen in this region. So, at 10000 nanometer you can expect, vibrational and rotational excitations. This you can, see around at 10000 nanometer.

If I still go, that is at 10 to the power of 8 nanometer, what your going to expect? Here you have going to, here what happens, you have an electron spin type of excitation. Your electron spins gets excited, but this can be done only in presence of magnetic field. So, we get electrons spin are excited, but this should be done in presence of, it happens in presence of magnetic field.

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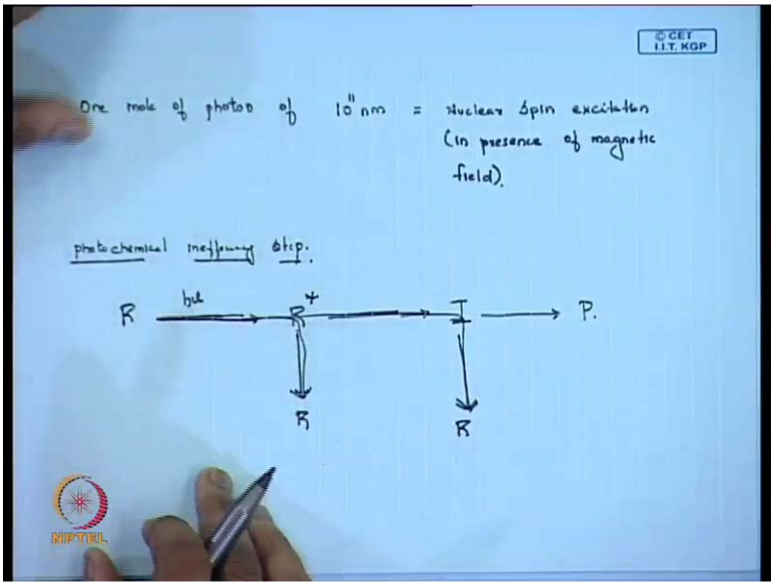

One mole of photon of 10^{11} nm = Nuclear spin excitation (in presence of magnetic field).

photochemical inefficiency step.

If I go, if I take one mole of photon of 10 to the power of 11 nanometer. What we are going to see around in this region, you will be seeing your nuclear spin excitation. Where you are a all you are n m R you try to do it right. So, that you are going to see in this region, nuclear spin excitation. This also should be done, in presence of, this happens in presence of magnetic field.

So, in photochemistry what we are going to try to do? We are going to concentrate, mostly up to your 500 nanometers. So, you see all your most of your organic photochemistry happening in this region, expect few in 60 calories, but most your chemistry happens from 200 to 400, 450 nanometers.

So, how to now the next question comes in your mind is that, how we can going to make this 200 nanometer, Because you have a light, how you are going to get 200 nanometer light, how you are going to get 300 nanometer light and 500 nanometer lights.

See, there as specific one if you have a lamp, it gives you a radiation of lights. So, you can use a specific filter, most of the time, you can use a specific filter, you can get that cross. For example, if I use quarts type of filters, then I get light greater than your 200 nanometers.

If I am going try to use pyrites, then its cut off from 290 to 310 nanometer, you gets light above that. For example, if you a use copper sulphate solution 350 and sodium nitrate solution like 410 nanometer. That is how, you can make the selective in your reagent, that how photo reagent became very selective. For example, I want to do some photo chemical reactions in the visible light. That is, a wave length of greater 410 nanometer. Then, what I do? I take the apparatus, I use a filter, the filter can be one mole of sodium nitrate solution, then I get a light around 410 nanometer. So, I can selectively excite the bond, or selectively do some photochemical reaction, where it needs 410 nanometer.

For example, I have a big molecule, and I want to excite only the particular functional group, which can be excited 350 nanometer. I do not want to touch other things, then you have like specific lights, which you can use.

For example, I want to do a chemistry greater than 350 nanometer. I do not want to affect any other compose, which are playing around 250, which can excite at 250. I want to do chemistry only greater than 350 nanometer, then you can use a copper sulphate solution, which will give you light after 350 nanometer. Like that, you can do some selection of your reagents.

So, that is why, this photons understanding about your reagent in R to R star transition place a important role. Once you know this, R to R star transition. One more thing, you have to understand in this step. That is, we call as photo chemical inefficiency steps.

So, we can call them as, it can call them as photo chemical inefficiency step, when you compared to that of. So, what I said initially, you have an R and this R as we said gets excited to your R star. We can say, now then your R star gets to your I, this I gives you the product P, but not true in all the case, that your R star should give you the intermediate I. Some time, what happens? Your R star can undergo a process to give you the starting material R back.

Like for example, your fluorescent process where your R goes gets excited to your R star, it does not want to give undergo an intersystem crossing, and then give an intermediate. Instead of that, this R star can come back to your R itself. So, it is get excited and get back your starting material itself. So, that you can have, in same way, there are cases, where your I can also get back to your R. So, this process where for example, I am giving a photon, is not been completely used to convert your R to P. What happens? This photons, some of this energy has been used, and then it gives be back my starting material. In some case, this intermediate can also give me the R back. So, basically we call this step as inefficiency step. This are very important, when you do your quantum yield calculations. That part, we will see in detail, how to do a quantum yield calculation there, this type of thing can occur.

Simply we can, tries to understand one more aspect of photochemical that is, product inefficiency can also takes place. That means, if I am doing a reaction, the R does not need to give me only one product P.

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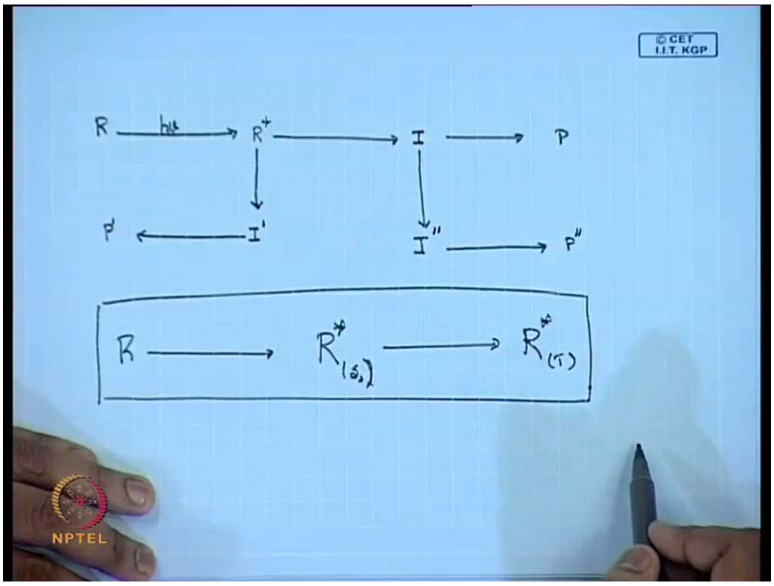

So, what happens? You have your R, this R kicks your h nu, it can get excited to R star. As I mentioned earlier, this R star can give me my R back or this R star can give me back my, give you this R star can give you the I, and then gives you P that is fine, but this R star can not only give you one intermediate, they can give me another intermediate which we call as I prime, and this can give me another product which we call as p prime. Same way, your I can also give me another product which is I, double prime we can call, and this can give me also another product can get P, double prime.

So, you see many things and happens. First case, we have said that R goes to R star, and gives me back my R. Second case, we have said see your R gets excited to R star gives me another intermediate I prime, which gives me different product product or my R star gives to I, and gives me I double prime, giving me different inter products. So, I am getting like three products. So, this two steps, which we call as this is photochemical previously what we discussed, this is we call some inefficiency steps, and this will call as product inefficiency step. This two you should understand, before we have to do quantum yield calculations right.

So, this is how, I am going to end up this, saying that see if you have an R - R gets excited to your R star, singlet and R star singlet can give me R star triplet. So, you will end up today with this note. From next class, we will start understand understand the second step, that is, how R singlet is converted undergoes intersystem crossing to give R triplet, and then R triplet giving you the I, and from I we can see how we can get the product P. So, from next class we will do that.