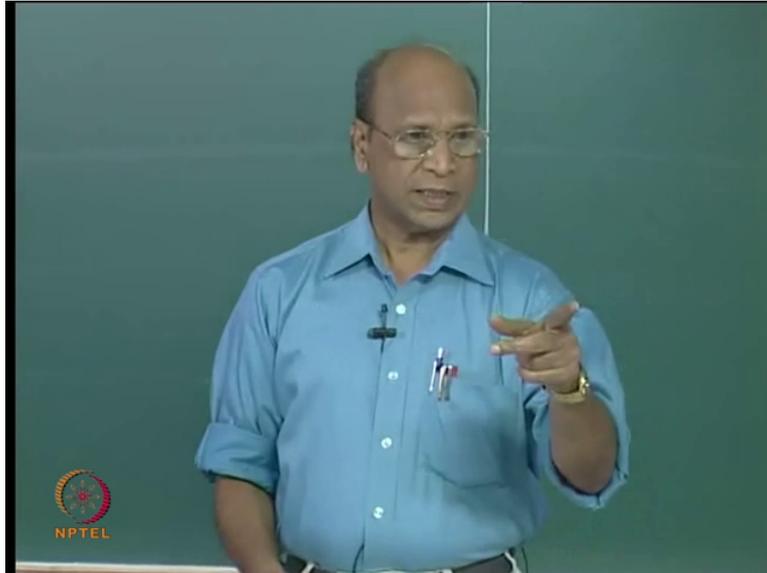


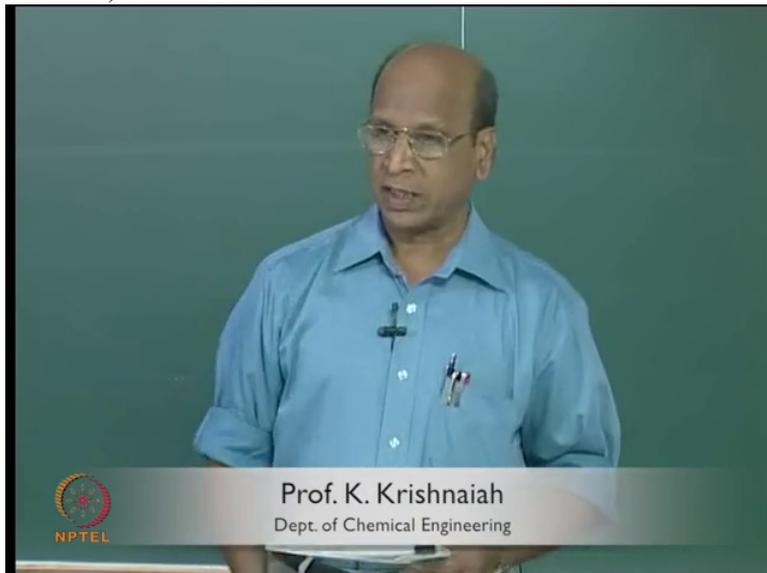
**Chemical Reaction Engineering 1 (Homogeneous Reactors)**  
**Professor R. Krishnaiah**  
**Department of Chemical Engineering**  
**Indian Institute of Technology Madras**  
**Lecture No 33**  
**Multiple Reactions Part 2**

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So we have discussed I think what is multiple reaction, what is single reaction, I have just given some notes there. And also various kinds of yeah, reactions, multiple reactions, series, parallel, parallel, series that Denbigh reaction

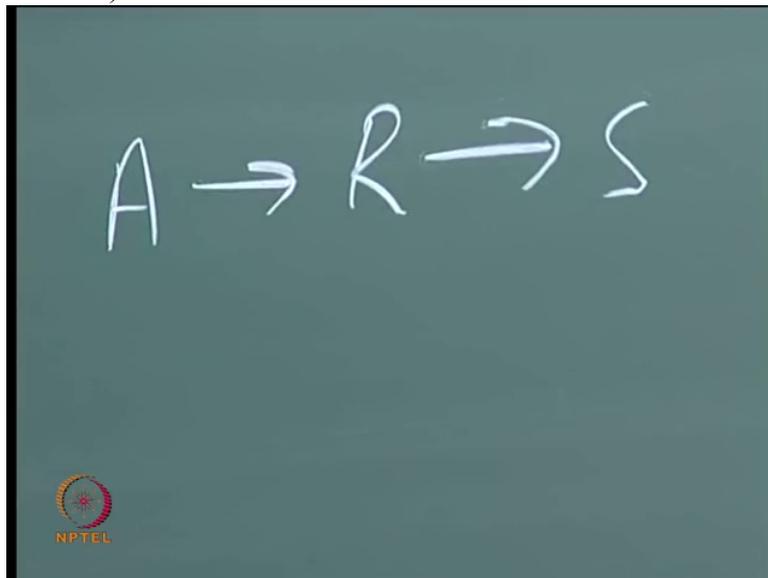
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is very famous reaction and also that van der Vusse, fan der Fusse, fan der Vusse reaction is also very famous reaction. Famous reaction in the sense you have the conflict, I think those conflicts we will see now; I mean what is the real conflict in those equations, right?

There are some more also, some reactions I will also let you know but before that we should understand the basics like we have what is conversion that all of us know. Ok, example if I have A going to R, R going to S, right, yeah so conversion

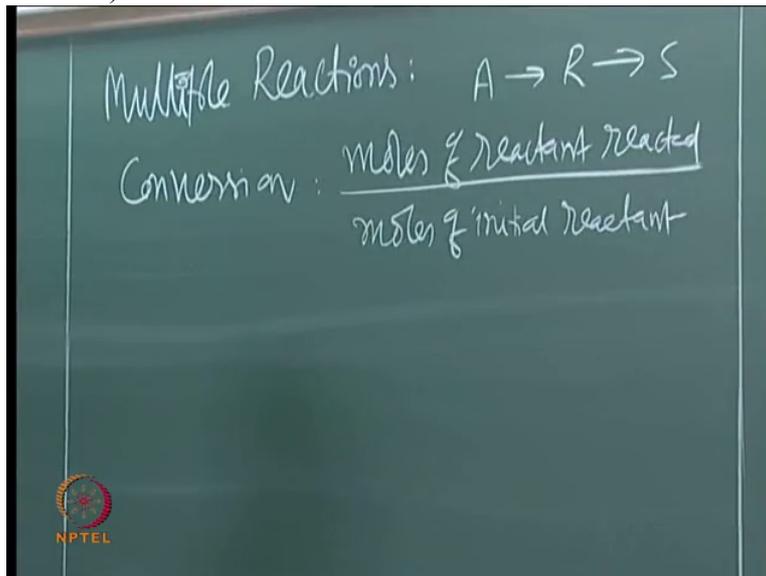
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always defined as moles of a reactant, key reactant reacted per, yeah reactant concentration fed. Ok.

So that we will write here, conversion, moles of reactant reacted or consumed by initial moles of initial reactant that means  $C_A$  naught for example,

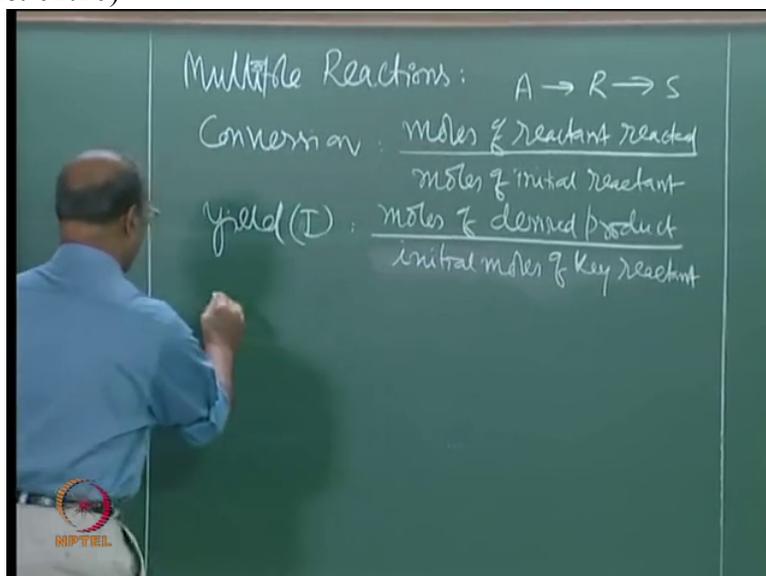
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right, that is one. Then we have yield, we have actually yield 1 where it is moles of, moles of desired product divided by initial moles of key reactant. That is 1.

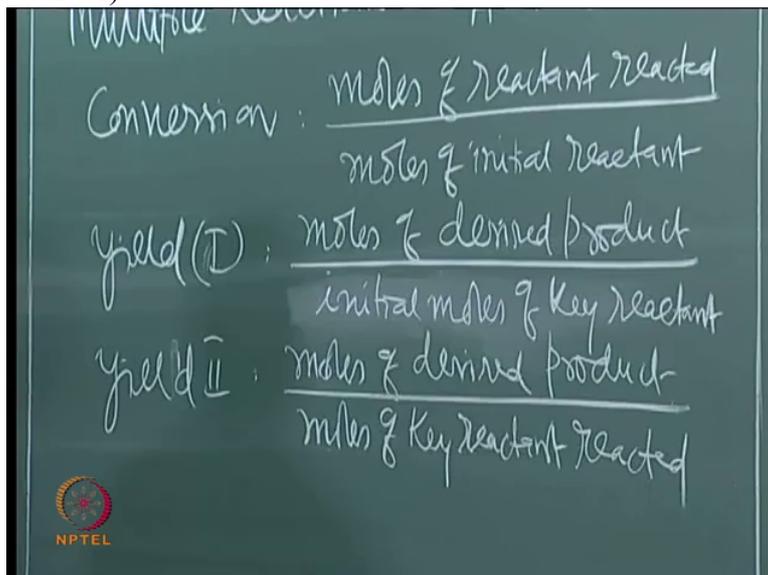
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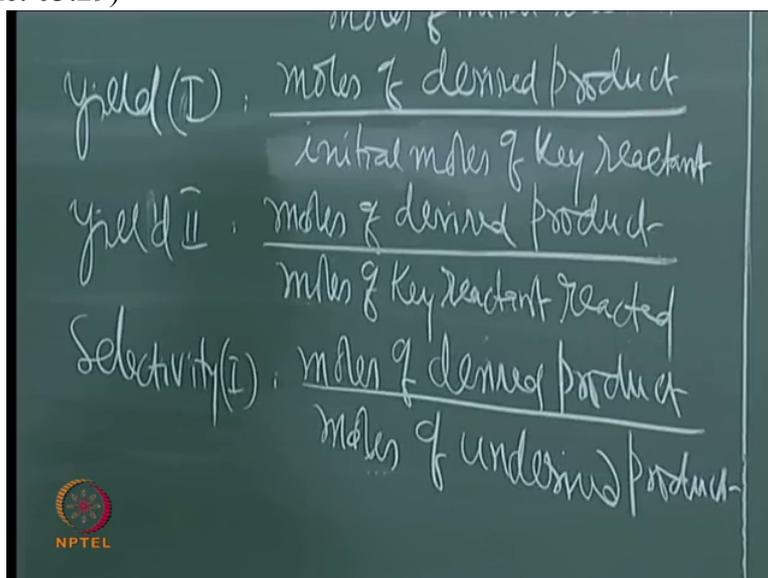
also you have yield 2 because you know different books will give different things, that is why we have to also just also note down this. Again this is moles of desired product divided by moles of key reactant reacted.

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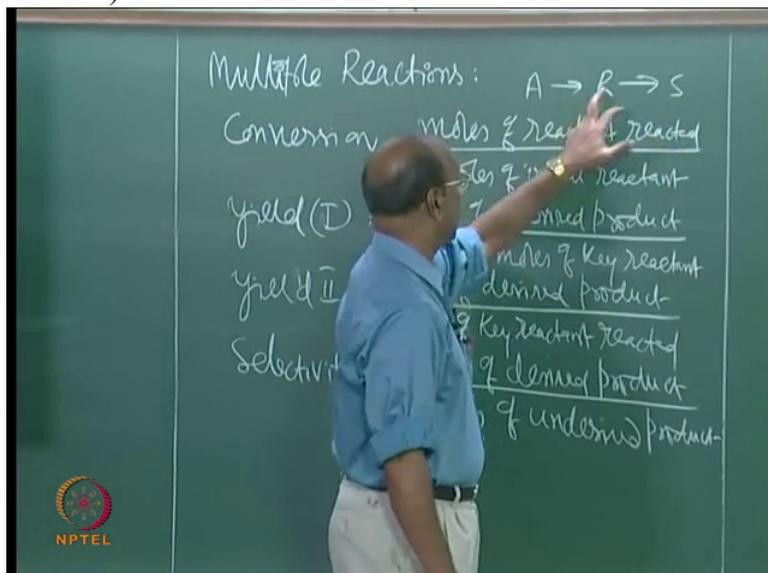
Then you also have selectivity. Again selectivity 1, moles of desired product divided by, yeah moles of undesired, yeah product,

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yeah. So this is one way that means you have to choose one of them. Right, that means you know I may have another here;

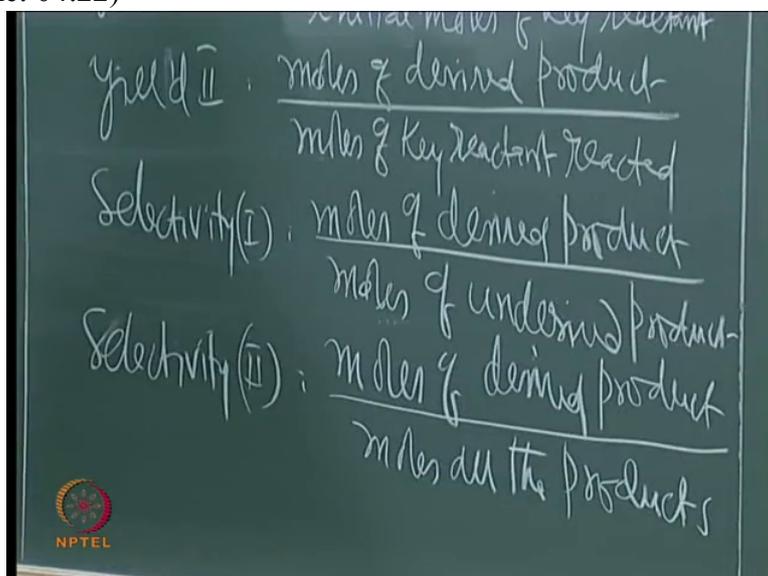
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desired may be this but here I may have again going to T for example. So you have to specify that. You are defining either based on S or based on T.

That is why the another definition is selectivity 2, is again this moles of desired, moles of desired product divided by moles of all the products. That is another way

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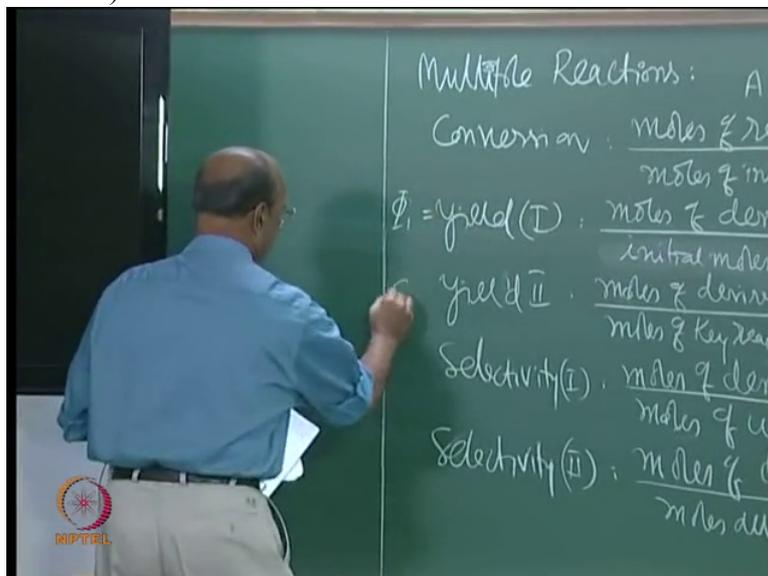
of defining. So that is why you know like heterogeneous reactions where you have various possibilities for defining rate itself, right.

You can base it on volume of the particles, weight of the particles, surface area of the particles, voidage of the bed, volume of the bed there are so many. Like slurry reactor also you take, you can express so many ways.

Similarly here also you have to choose which one is the suitable for you, which will minimize your mathematical representations. Ok, so that is what, good. So this is what are the definitions generally used. Ok, good.

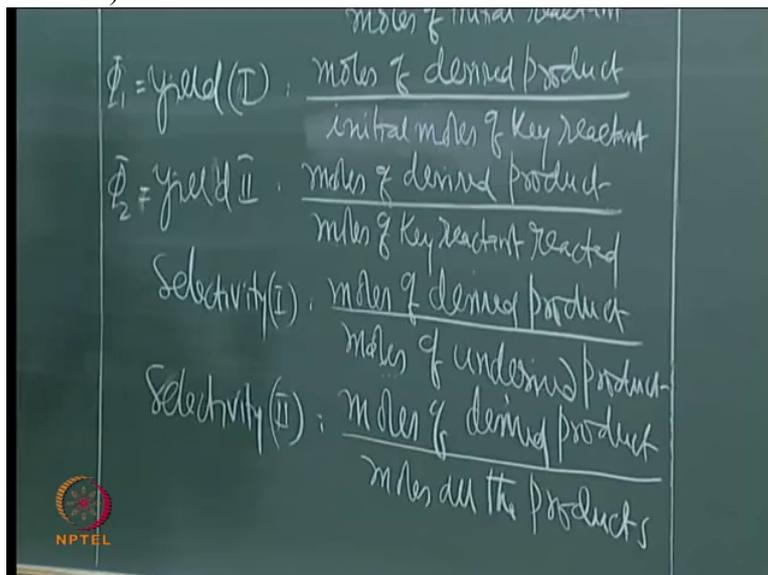
So now once we have these, normally we try to use this one as phi 1, this as

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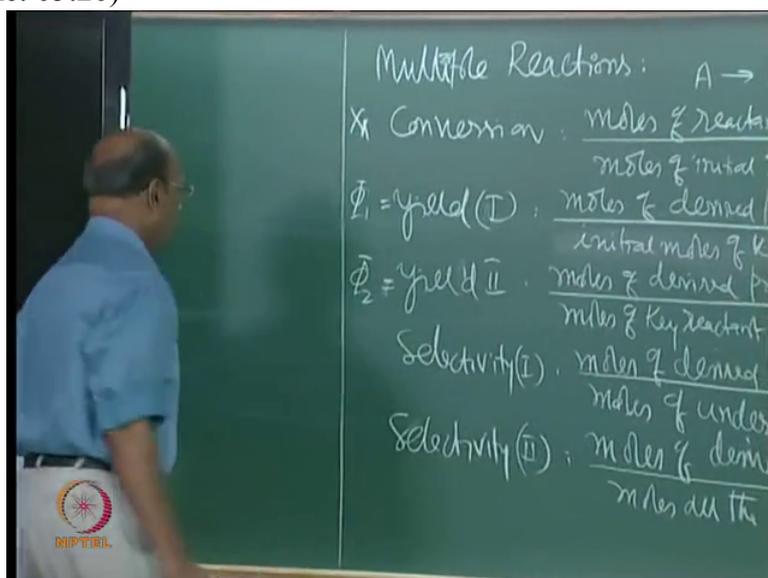
phi 2. These are the two things which we generally try to use.

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And of course conversion will be there any way. Conversion you know. Conversion is X A only,

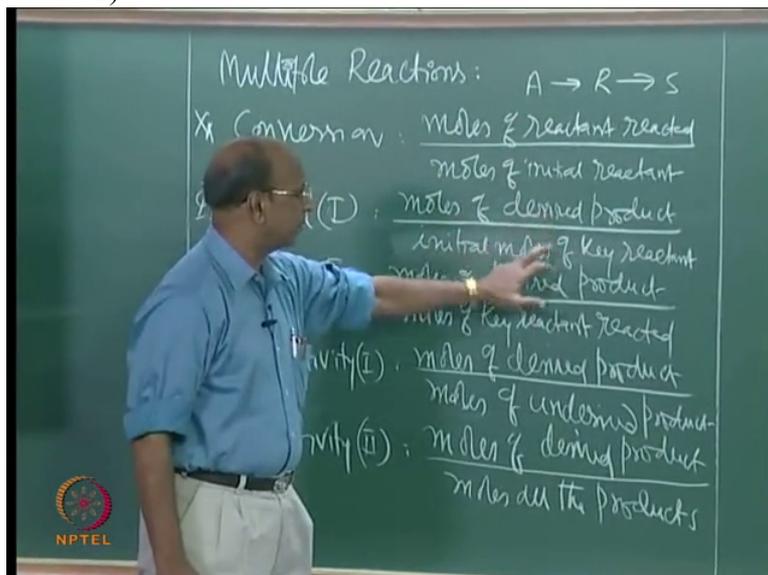
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Ok.

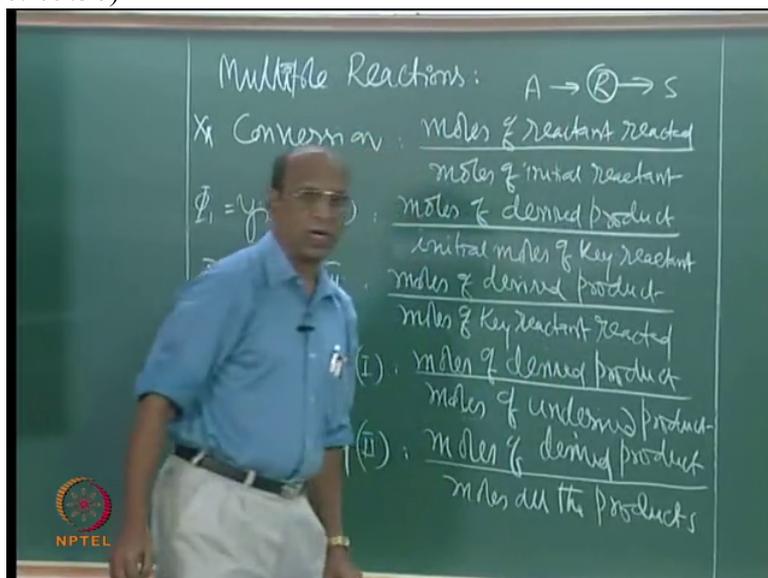
If you see for example, Carberry book which I have been telling you, he uses phi 1. That means always this will be in fact in this case, what is the equation

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for this in this case? Desired product as usual I told you R.

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Ok this is C R by...

(Professor – student conversation starts)

Student: C A naught

Professor: C A naught.

Student: C R by C A naught yeah

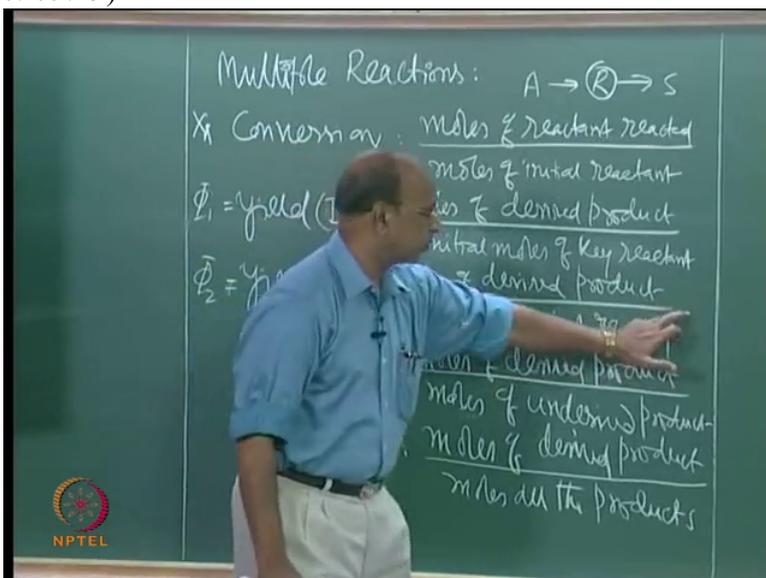
Professor: C R by C A naught, Ok

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so like that. And whereas this one, next one?

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Student: 0:05:50.2

Professor: C R by

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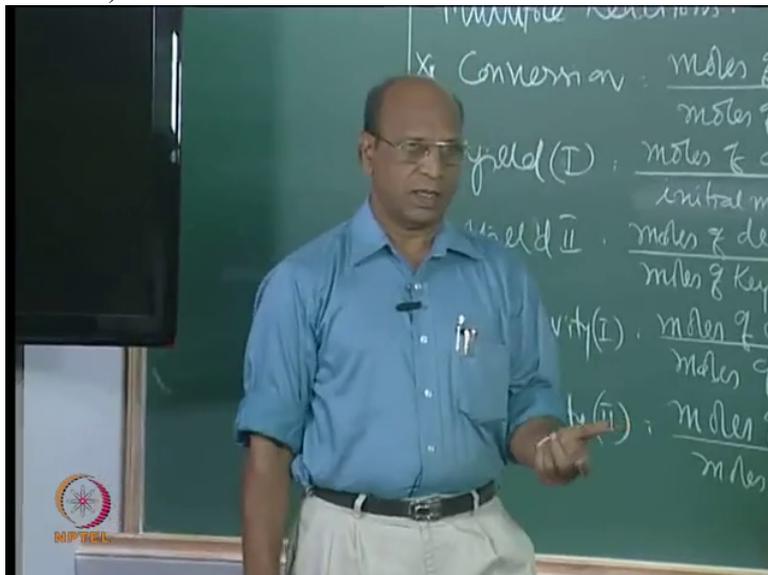


Student: C A naught actually

Student: C into X A

Student: 1 minus X A

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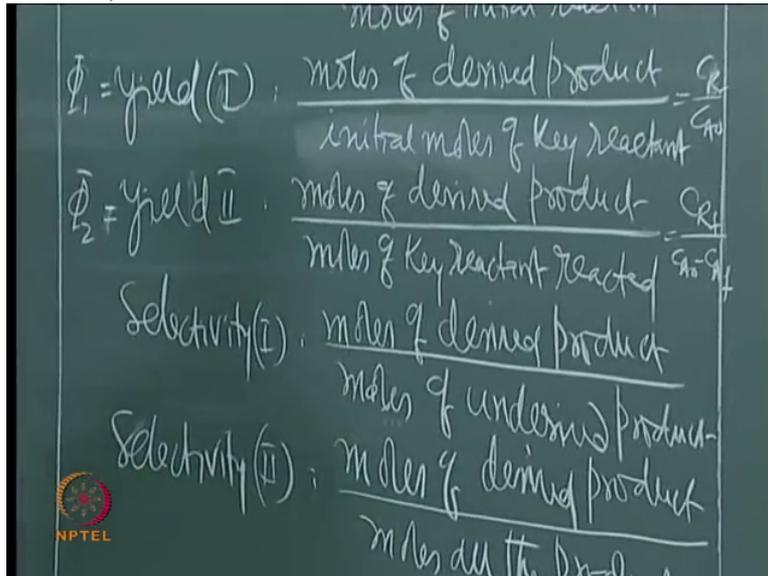
Professor: C A naught minus C A.C A naught minus C A. Ok.

(Professor – student conversation ends)

So I think anyway, may be you are getting confused. Let me write here. This is C A by, C R by,



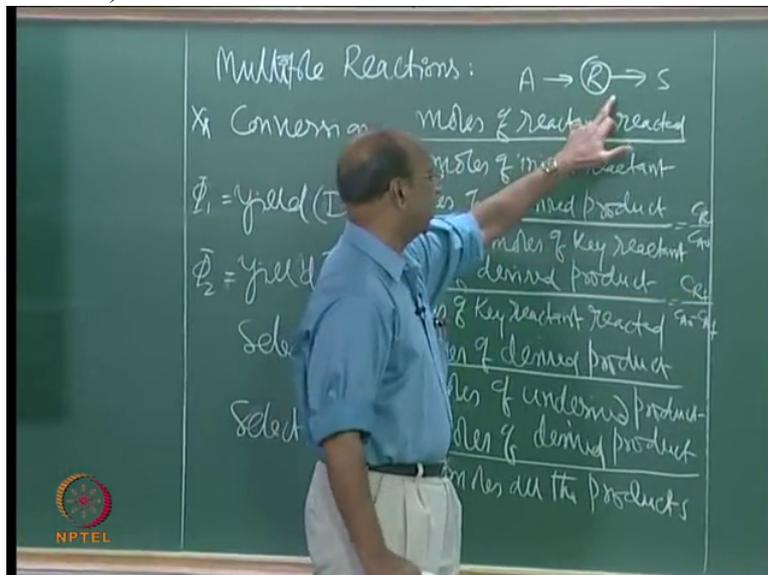
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So those are the things. So this is what we use and Levenspiel uses most of the time this, and Carberry uses this, right? Ok.

So then what is the method of finding out this yields and selectivity? Because these are all in terms of now moles or in terms of the concentrations. Now we have to find what is

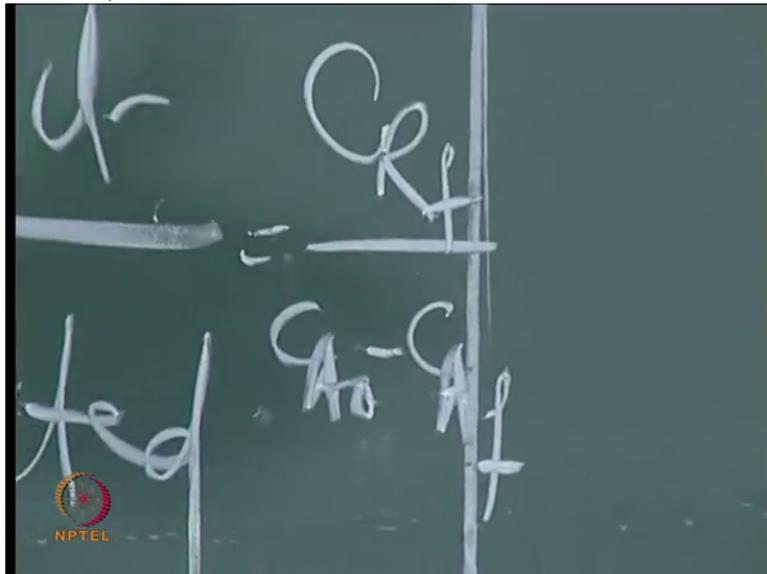
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C R by C A naught if I ask you what is the yield 1, right? So if I ask what is yield 2, C R f by C A naught minus C A f?

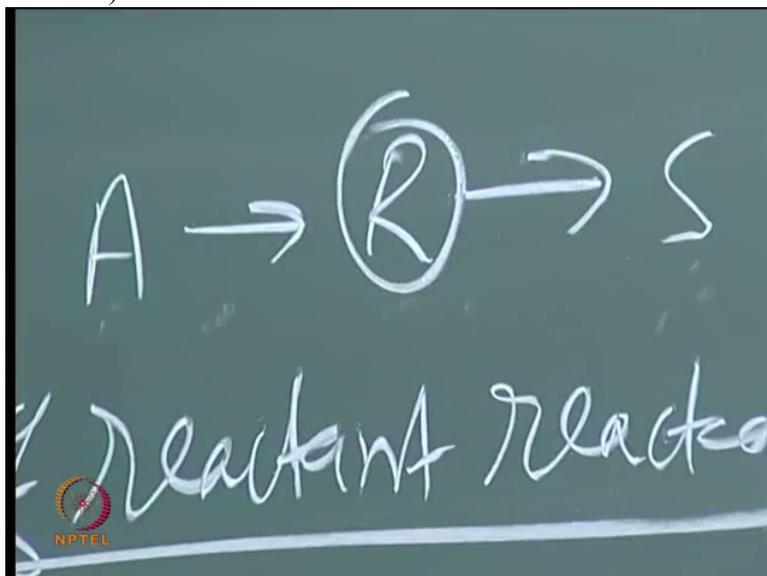
So why I am

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telling this one is I am trying to give you the connection. In the third chapter itself you have derived an equation for this A going to R, R going to S, Ok. So you could have derived what is

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C R by C A naught. Correct no, you have done that. So that is what. That is what is yield 1, right?

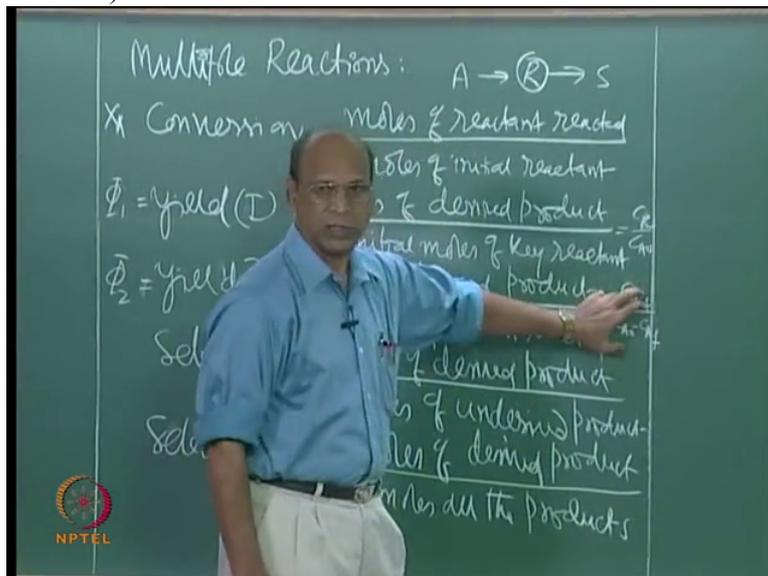
So one way of going with all this is, straightaway going to the equations like you know first order reaction if I have, this is first order, this is first order. And also yeah these two are first order reactions. Then I write the rate equations. If it is elementary I know how to write equations. If it is non-elementary then I will have to tell you what is the rate equation.

Then go to corresponding reactor and I am just trying to give you the overall picture. What is the reactor? I may use batch reactor, or I may use continuous reactors, plug flow reactor or mixed flow reactor or I may use recycle reactor sometimes, Ok. Or I may use semi-batch reactor also sometimes, right?

So you just, you know the equations for at least the recycle reactors and other three reactors, batch, plug flow, mixed flow, recycle reactor. And semi-batch we have not discussed here but again that is only writing the material balance like we have written for all other reactors, right. So you have to find out now, then which reactor, you have to take one rate expression, one way of doing.

And then use first batch reactor or mixed flow reactor or plug flow reactor or recycle reactor and then try to find out which one will give you maximum for yield 2, if you are using this equation.

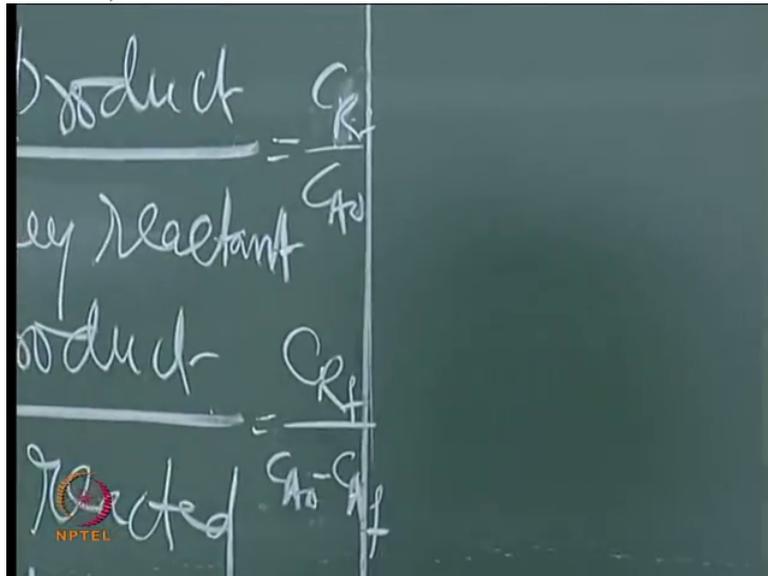
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Or maximum for C R by C A naught.

That means

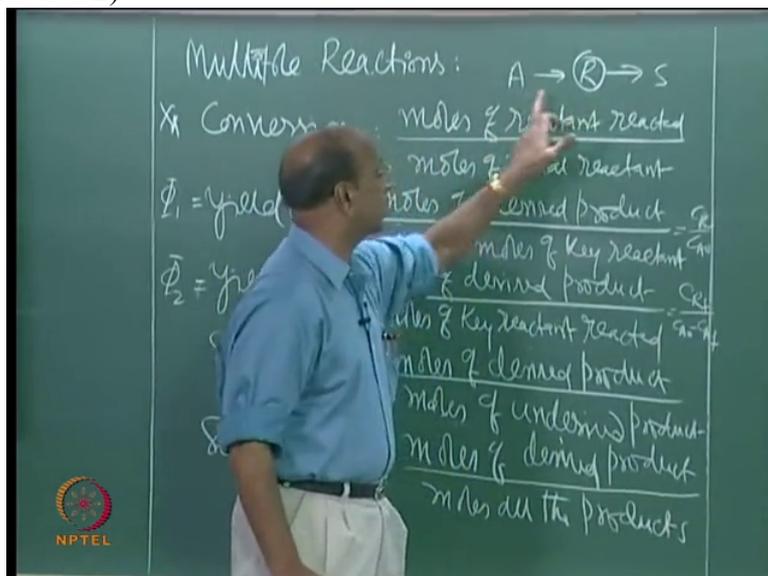
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for every reactor you will get, for some given production rates, you will get one value for C R, C R by C A naught. That phi. So then try to find out which one will be the, you most, know, better suited reactor.

That is why I told you sometimes recycle reactors are better than even plug flow reactor depending on what kind of scheme you have here. This is one scheme

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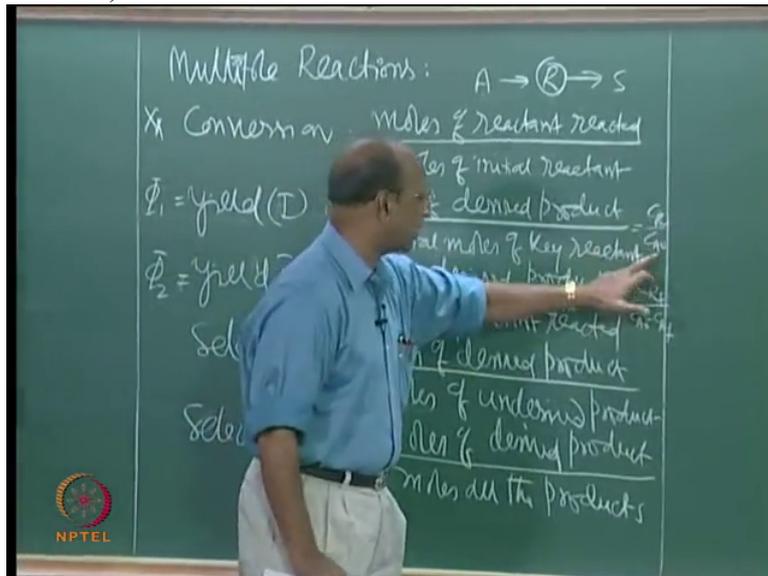


A going to R, R going to S. There is another Denbigh scheme. What is Denbigh scheme? Again A going to something else, R going to something else.

If this is the desired product, then we have real optimization problem in our hand. So you have to take one particular reactor, for example mixed flow reactor as an example and then try to maximize by writing all these equations, where do you get that maximum C R by C A naught, Ok, C R by C A naught that is this, if I am talking about yield 1.

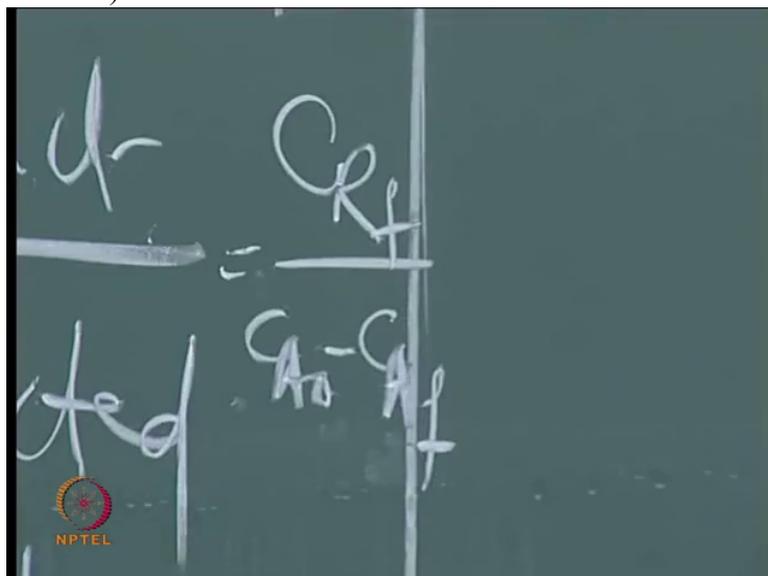
And yield 2, once you know C R by C A naught,

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we can also easily calculate what is C R by C A naught into C A f. Because C A by C A naught already I know. Ok, I mean

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in the derivations you will automatically get it. So the overall picture is that. Going to each individual reactor and then try to find out.

That is the approach taken by Carberry and Smith, all these. All the books you may have around 20-25 books. They can be divided into two parts, followers of Levenspiel, followers of Smith, Ok. In Smith and all that you know, you will never get epsilon and all that. I do not know whether those people who have used Smith book, there is no epsilon there, epsilon A. Ok. Whereas the followers of Levenspiel, in all those books you will have

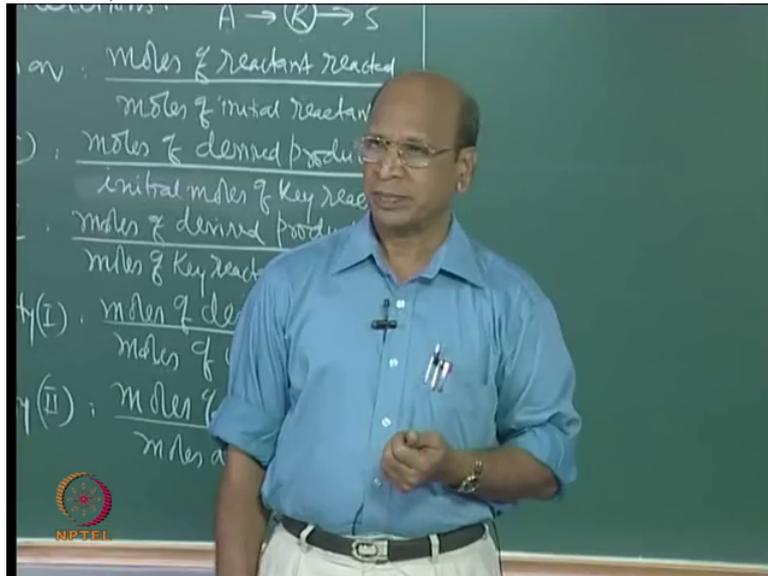
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epsilon A.

That means, I mean what is the difference? Both should give you same answer. You cannot get for Smith one answer and Levenspiel another answer. You should get the same answer, Ok. But what is the advantage or disadvantage in these two processes? Delta x improvement, brain, expanding the brain.

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What is the advantage or what is the disadvantage,

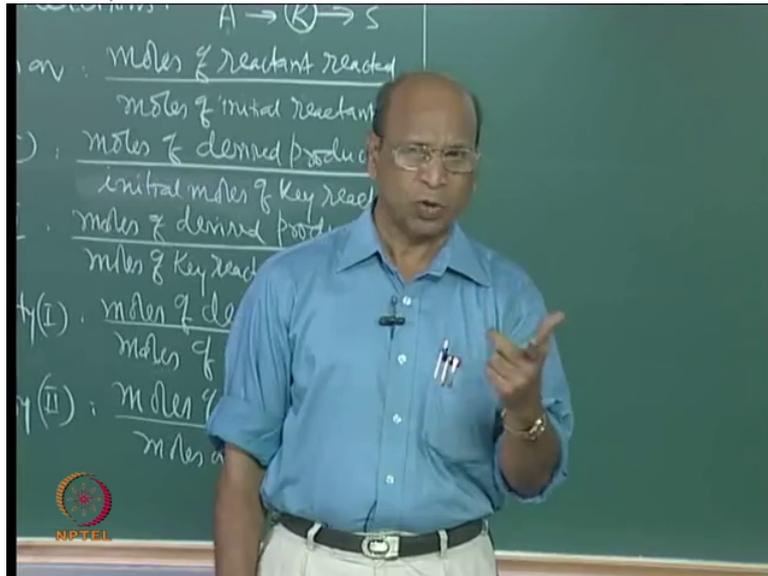
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particularly for gas phase reactions and all that?

So that means you have not used any other book

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than Levenspiel? Fogler? Fogler is cousin brother of Levenspiel. He also used epsilon.

(Professor – student conversation starts)

Student: 0:10:52.3

Professor: Ok, yeah. So you have not gone to some other family. This is Duryodhana and Pandavas family, (laugh). Ok, yeah. So I think I do not know most of you have gone to only that approach.

(Professor – student conversation ends)

Actually both are right but mathematically you will have more complications in the other approach where, you know Smith approach where every time you have to write mole fraction multiplied by, you know concentrations, all that will, thing will come.

That means every time you have to write what are the total number of moles, then you find out mole fraction, then you calculate total pressure multiplied by mole fraction what you get partial pressure, so most gas phase reactions in these books, Smith and other party, you know their party books, only solve the problems, gas phase reactions in terms of partial pressure. Ok.

Yeah where as Levenspiel, this epsilon, you can still use partial pressures and all that. But his thing is directly using that equation  $y_i$  into  $\Delta$ .

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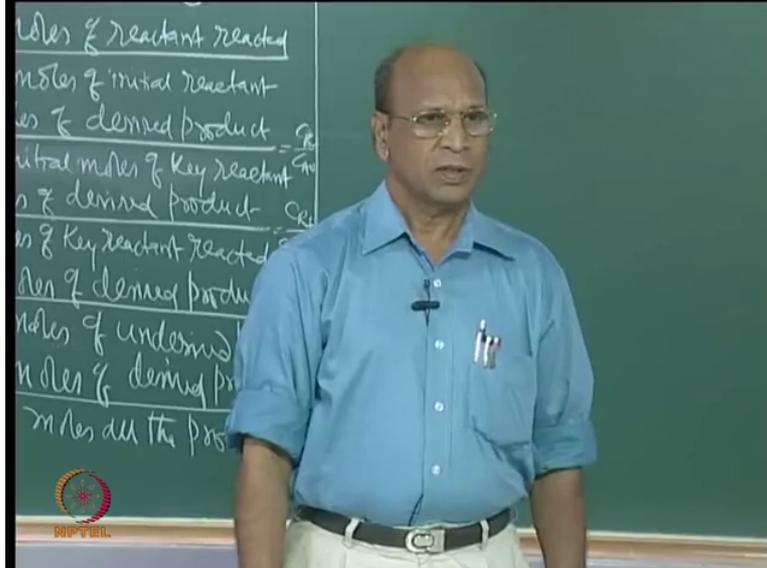


(Professor – student conversation starts)

Student:  $y_i$  naught delta into A

Professor: Yeah,

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so that is all. That means you do not have to remember any other thing.

(Professor – student conversation ends)

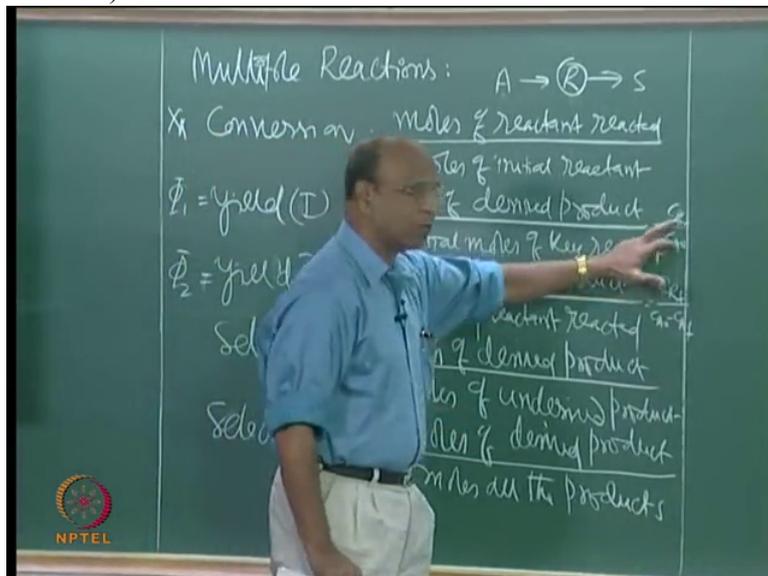
This is simplifying. So you are generalize things so that it is easy for you to remember and just proceed. But I think you are trying to proceed so mechanically. You do not know why

this has come, why that has not come. So that is why I am trying to tell you at least this point of time, you have two approaches.

One is by using epsilon directly. The other is one by writing only the number of moles, Ok total number of moles, mole fractions and then calculating partial pressure and then trying to integrate but that is strictly for which reactions, gas phase reactions that too, changing moles, Ok. That is the restriction. That you have to remember.

So that is why, again here, Carberry and all, Carberry and Smith they belong to one school. He always writes, in fact Carberry

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book is the excellent book for yield and selectivity. Really excellent book. So many problems he has dealt with. And all of them are mathematics.

He takes particular reaction scheme like for example that van der Vusse equation, Denbigh I think he has not done that well, so van der Vusse equation he takes and then he will try to solve for mixed flow reactor, plug flow reactor.

Plug and batch both give you the same equations. Only one is  $t$ , the another one is  $\tau$  that is all the difference because we are talking about constant density systems most of the time when you are talking about multiple reactions. Again the reason being that let us first

understand what is happening in multiple reactions rather than complicating the problem with mathematics.

I told you no, if you have too much mathematics, beyond certain point of time you will forget what is the actual problem. And you will only remember how to solve this problem using some mathematical technique. So it becomes mathematical course.

Right that is why we call  $dy$  by  $dx$ . We do not know which problem you are solving, right? Or  $d^2y$  by  $d^2x$ . Which problem you are solving? You do not know. Because  $y$  can be anything,  $x$  can be anything. That is what you are going to do exactly if we maximize the mathematics when you are talking about any subject.

So that is why physics is important for us as engineers. What problem am I solving? Because this mathematics is a tool for me to finally get some relationship between concentration versus time. Ok. Or versus length if it is continuous flow reactor. Or if it is there is a change in distillation

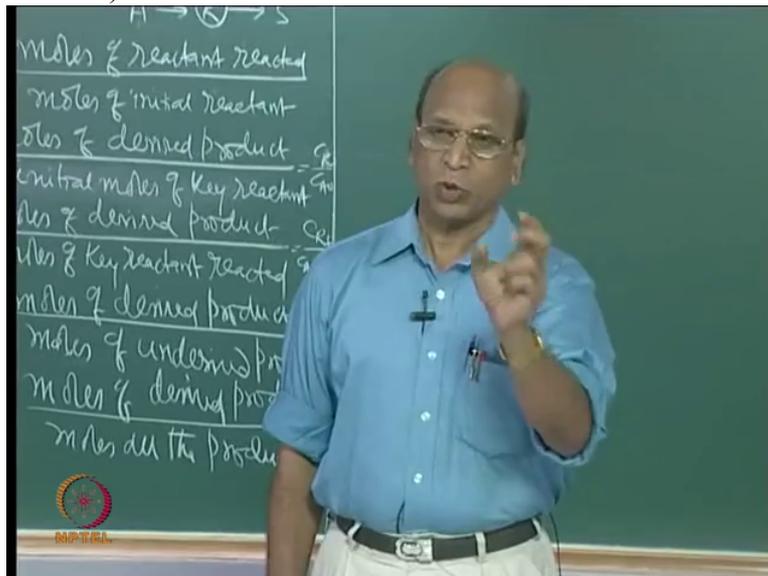
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column I would like to find out what is the concentration change along the height of the column, right? Or absorption also same thing. So that is why.

You know, that is the actual problem.

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But to solve that you have to use very, very difficult or different mathematical techniques to get that particular solution. Right. So that is the approach what they take.

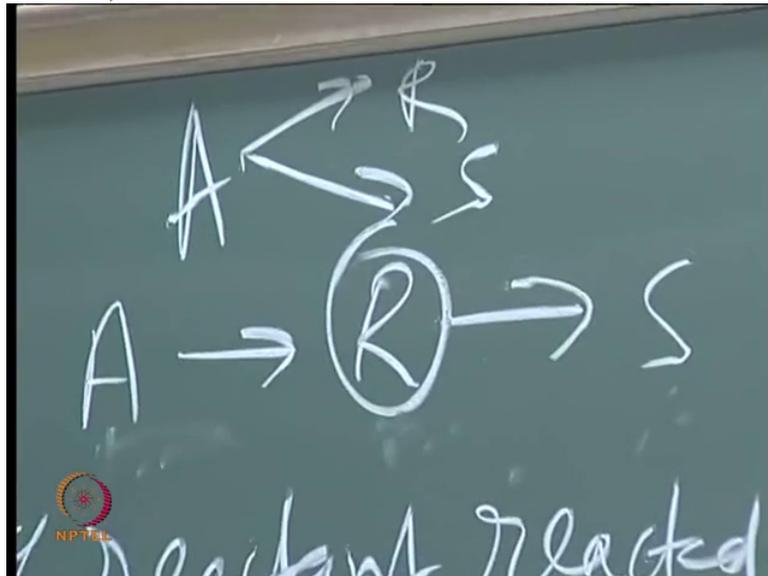
And now I am trying to justify Levenspiel. So that is why am telling all this. So that is why if you see no, those who have used Levenspiel and also those who have done multiple reactions, he gives some rules. For parallel reactions what are the rules. Anyone remember? You do not have to tell me the rules but at least do you remember there are some rules?

For parallel reactions, what kind of reactors will be better? For series reactions what kind of reactors are better? For series and parallel combinations also what kind of reactors are better? So that means by looking at A going to R, R going to S you have something in your mind that Ok, this reaction is, this reactor is good.

So that way it may be spoon feeding but still that gives you some kind of remembrance where Ok, by going from A going to R, R going to S, you are going to feel that Ok, in fact plug flow reactor is better. Mixed flow reactor will not give you that much yield as compared to plug flow reactor when, strictly when you have A going to R, R going to S.

But again that is for simple,

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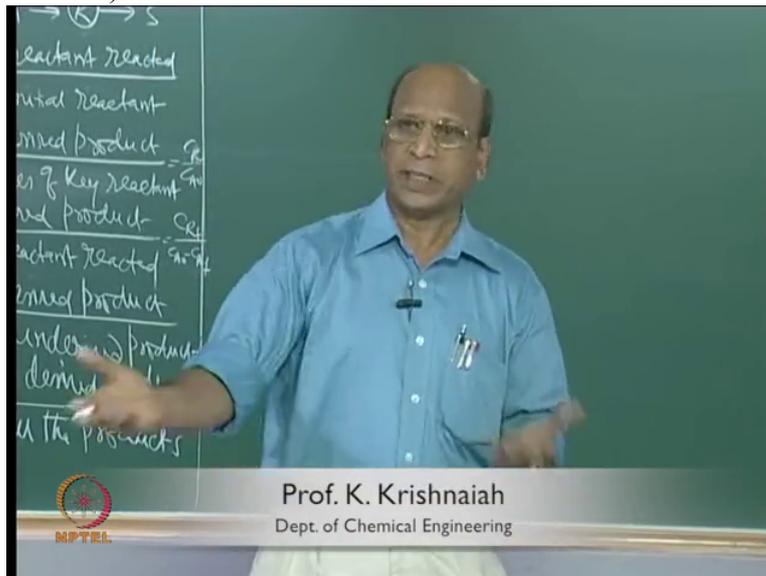


simple A going to R going to S or simple A going to R, R going to, A going to S. This, for simple parallel reactions and simple series reactions. But when you have again too much complicated things, for example Denbigh reaction you cannot tell. Because you have parallel as well as series reaction. Ok.

So that is why first let us see these kind of rules first and then afterwards we will try to solve the problems and it is now, you do not have to learn any new conceptual techniques but it is only the mathematical techniques you have to learn. I am repeating thousands of times this mathematical techniques.

And I know tomorrow morning, first order differential equation you cannot solve if I give you a problem and then you blame that you know, the question paper is very lengthy, Ok. If you do not know anything it can be lengthy

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I say. What is by lengthy? I am not giving 10 kilometers length question paper. Only A 4 sheet I am giving. Correct, no? What else am I giving? I am not giving anything else.

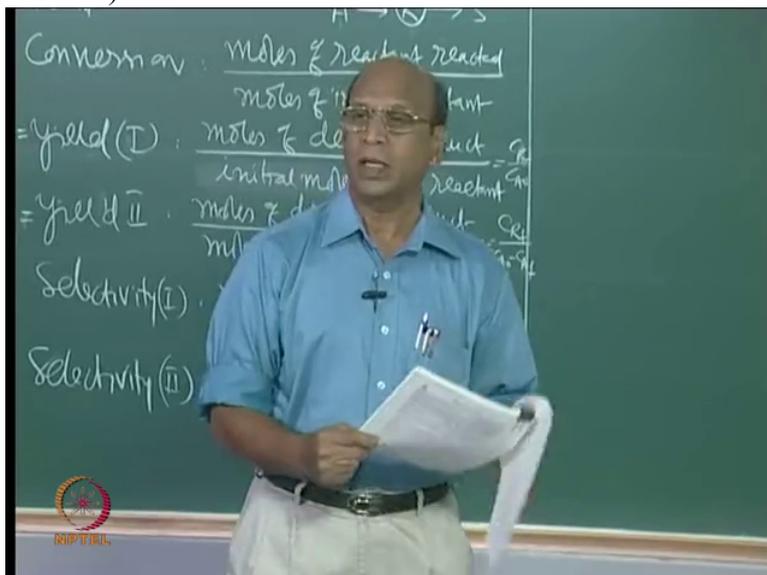
But because as I told you if your writing speed is zero, you will take infinite time. Who can wait till infinite time? Even this universe cannot be there till infinite time. At some point it has to go, right? So

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that is the reason why those mathematical techniques are very, very important for you and you have to work, you have to work, you have to work

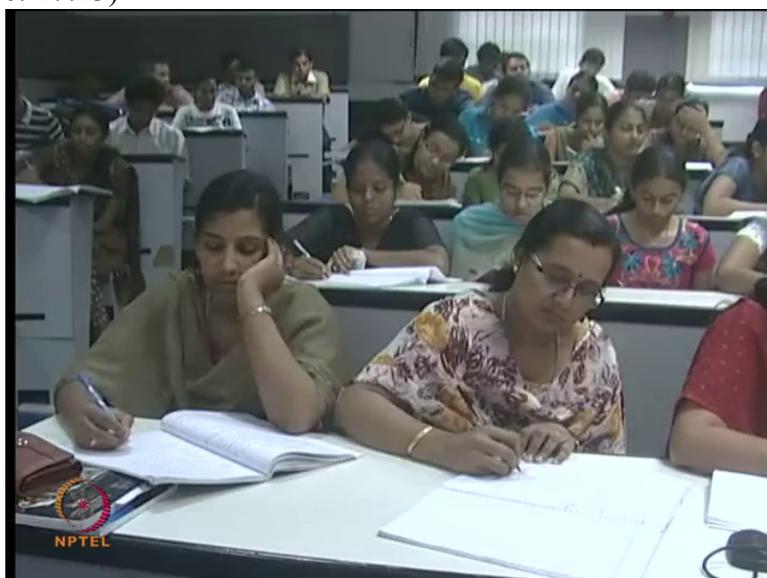
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to get marks also in the examination, Ok. Good.

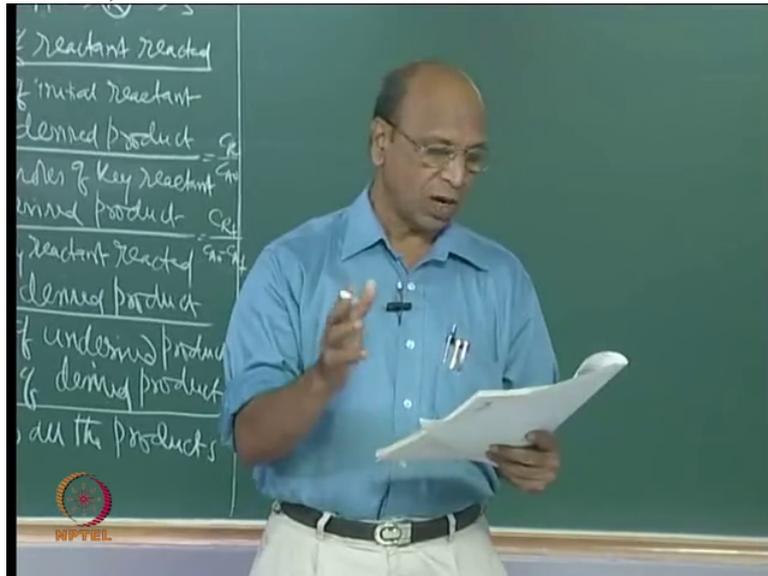
Please take this. For analyzing multiple reactions let us assume density, in the bracket epsilon  $\epsilon$  equal to zero and the reactions are elementary to understand the concepts.

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In real world the concepts learnt here are still valid but

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the algebra will be messy. That means you know

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you will have more complicated algebra there, equations.

So now of course we have derived what is conversion and what is yield, then yield and again most of the time we will try to express our things in terms of yield rather than selectivity. But some books, quickly I think someone was telling, you know, that Engineering of, that is a beautiful name, Engineering of Chemical Reactions. Which book is that, who has written that book?

(Professor – student conversation starts)

Student: Denbigh

Student: Denbigh

Professor: Denbigh is beautiful. Chemical Reactor Theory, course name.

Student: Schmidt

Professor: Schmidt, yeah. Schmidt and Smith, there are two people.

Student: James Smith

Professor: Spelling?

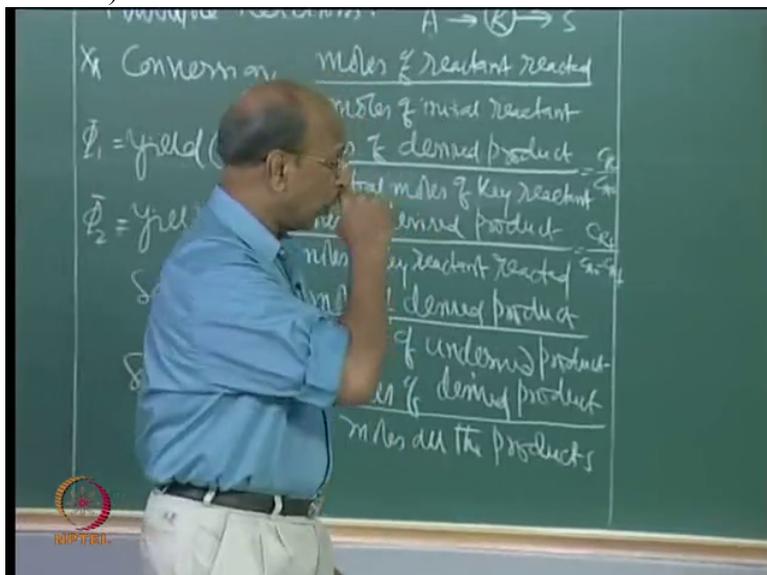
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Student: S c h m i d t.

Professor: Schmidt, Ok, yeah. So

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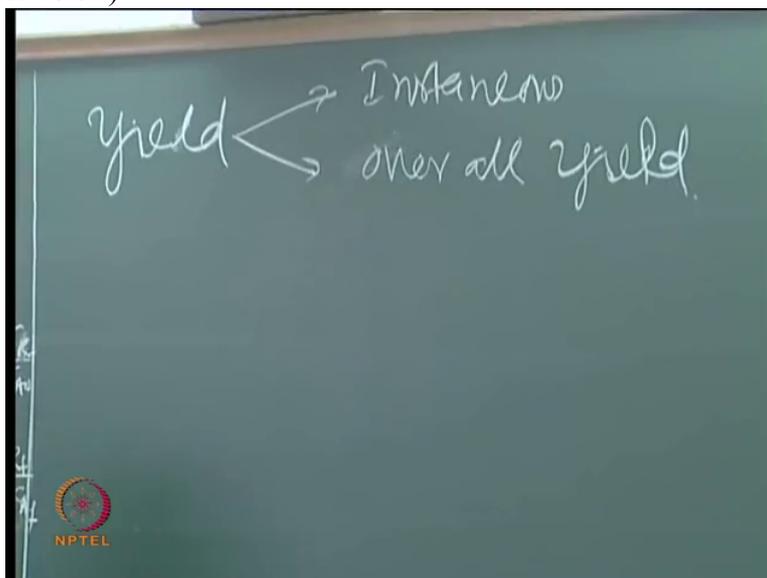


he has used, again I think it is only selectivity what he talks if I remember correctly. I just looked some time, long time back. Only selectivities he will use. So that is why it is only our personal choice. And also mathematics there and here also it will be equally same, right.

(Professor – student conversation ends)

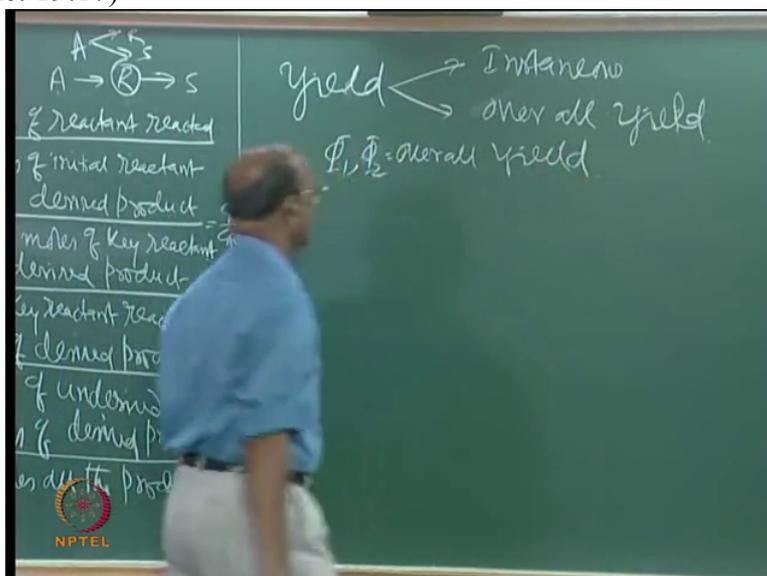
So yields only we will take and yield has again instantaneous yield, instantaneous and overall yield. And overall yield, Ok. Yeah, this is overall yield.

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In fact what we have discussed here,  $\phi_1$  is the overall yield. Ok and I can also write  $\phi_1$  and  $\phi_2$ , all overall yield,

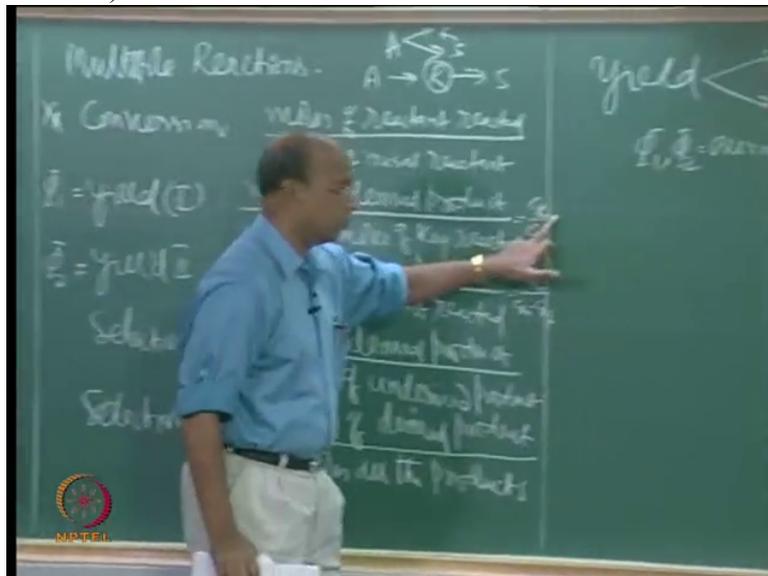
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Ok.

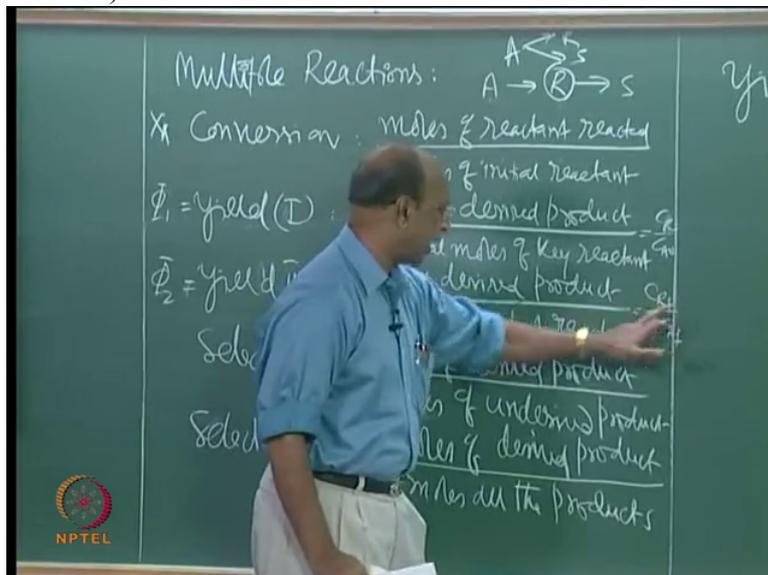
Why? Because at the end only we are writing this.

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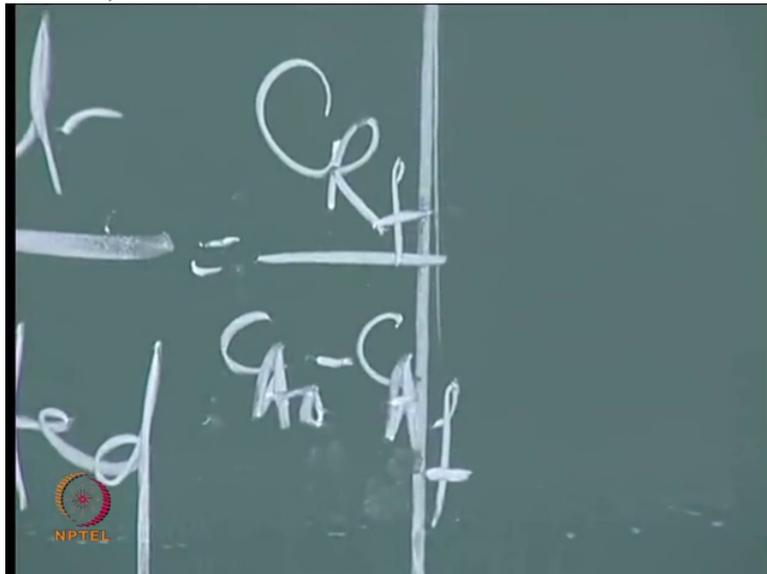
At the end of the reactor what we have  $C_R f$  divided by  $C_A$  naught. And for  $\phi_2$ , it is

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$C_R f$  divided by  $C_A$  naught minus  $C_A f$ , Ok because we came again outside the reactor so what happened in the entire reactor only

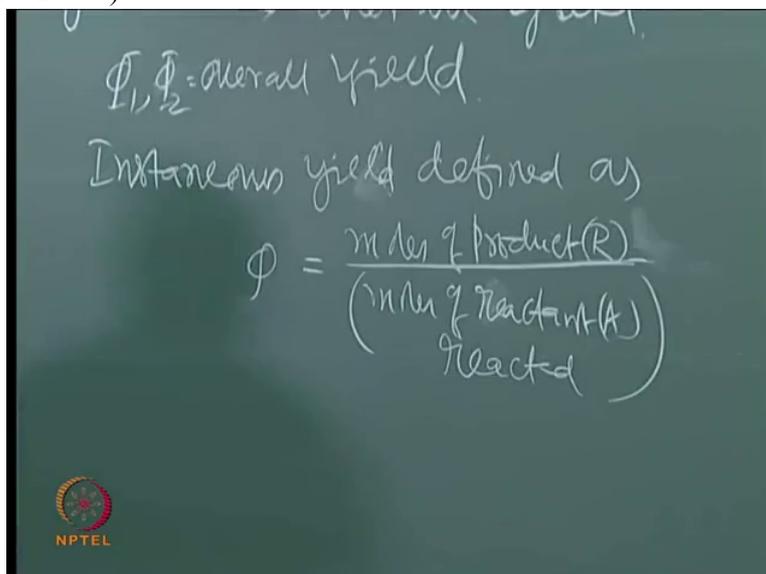
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we are taking. That is why it is called overall yield.

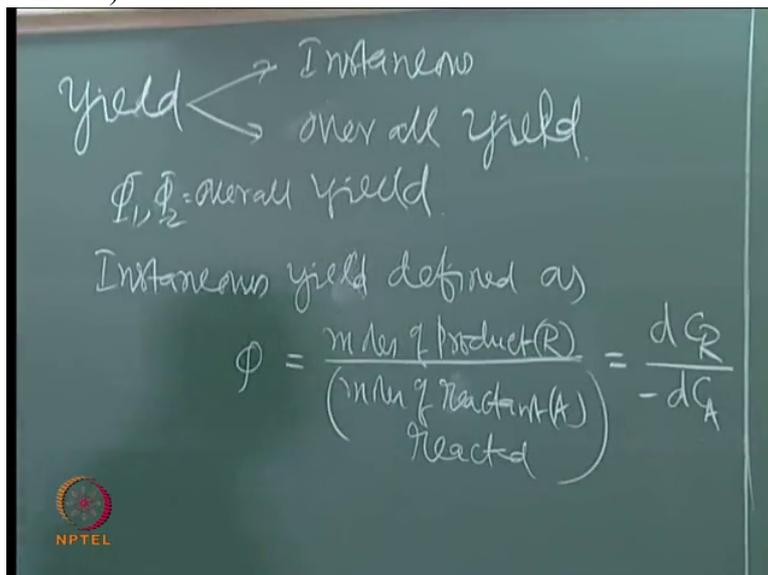
But anytime inside the reactor when I look, I may have the instantaneous yield defined as, instantaneous yield, yeah defined as, this is small phi equal to moles of product, that means let me say it is R formed, Ok by moles of, moles of reactant, again A, reactant.

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So this is written as  $dC_R$  minus  $dC_A$ .

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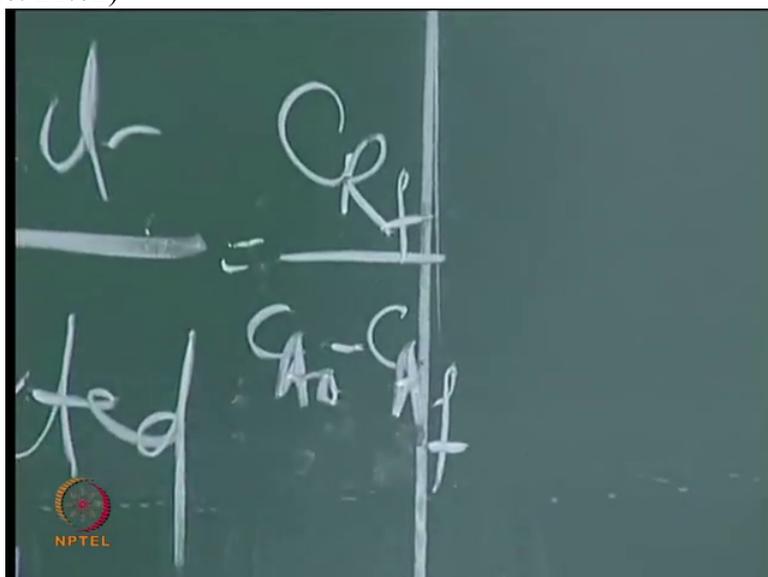
Ok, why that minus?

(Professor – student conversation starts)

Student: 0:20:47.9

Professor: Yeah, definition of that derivative is you know, always  $C_{A2}$  minus  $C_{A1}$ , Ok, but now here we have written  $C_{A \text{ naught}}$  minus,  $C_{A \text{ naught}}$  is larger, actually it is supposed to be  $C_{A f}$  minus  $C_{A \text{ naught}}$ ,

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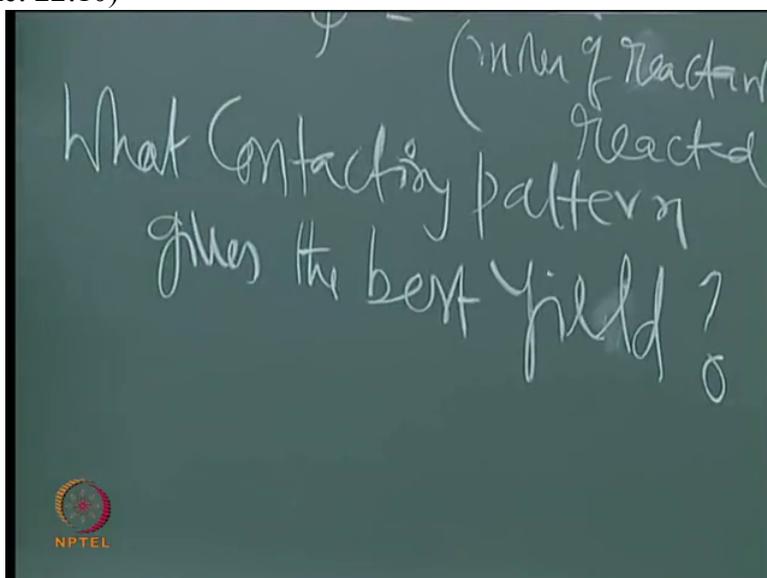
Ok. So that is why that minus is given there, so that you will get a number here positive, right, positive quantity, good.

(Professor – student conversation ends)

So this is the instantaneous yield. And now this instantaneous yield we have to find out depending on the reactor whether we have plug flow reactor, what kind of instantaneous yield equation you get? Or mixed flow what kind of equation? Or batch reactor, what kind of equation? Ok.

So that quantification we will go a little bit later. But right now what we have to discuss is to find out, I know this yield I told you, instantaneous yield, what contacting pattern will give us the best yield? That is the question.

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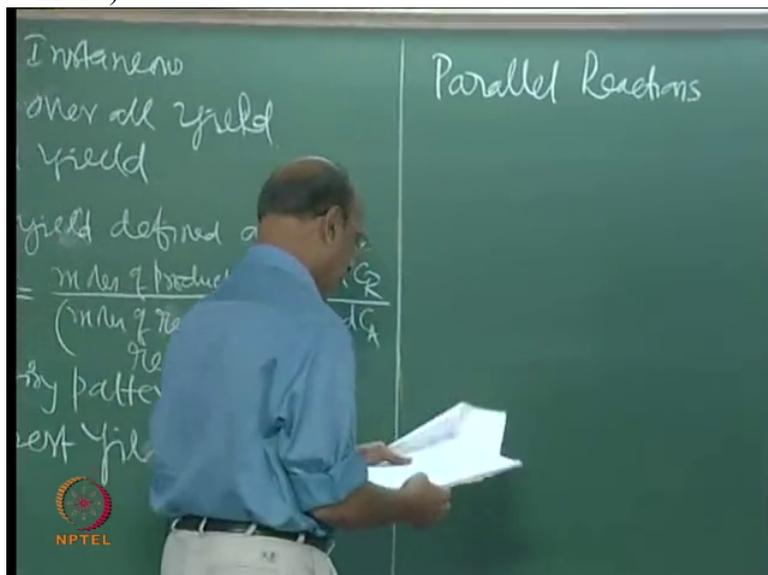


Ok. What is the question?

Question is what contacting pattern, I hope you remember what is, you know, it is a long time I have drawn my diagram, long time back Ok. So do not forget that. What contacting pattern gives the best yield? Y i e, correct, that is the question. Ok what contacting pattern means in other words; what you are asking is, yeah.

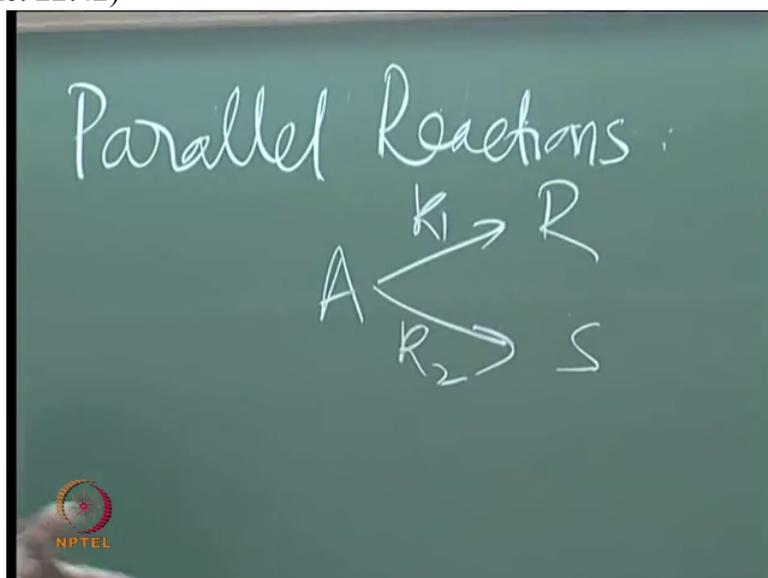
So let us do that for parallel reactions first. Parallel reactions.

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In parallel reactions, let us take the simplest scheme. It is only just to get the rules first. Yes this is let us say  $k_1$ ,  $k_2$ , Ok this is the scheme. And we told these are elementary reactions.

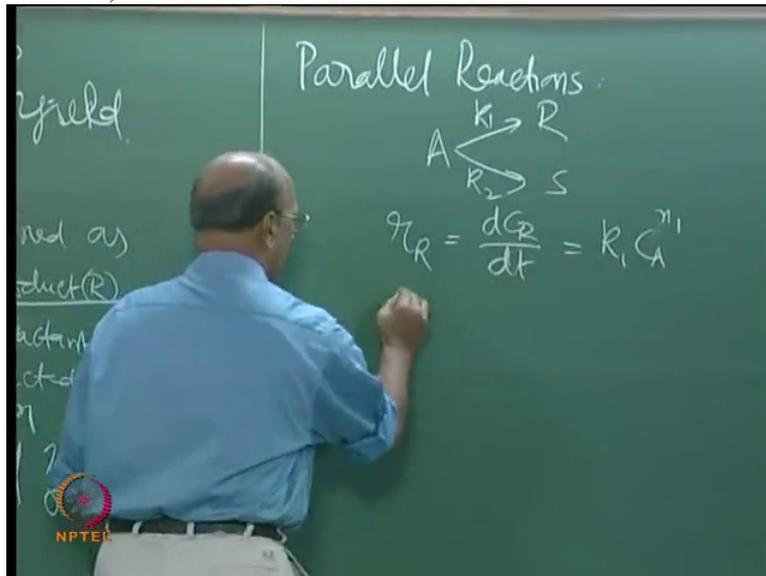
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So it is first order only, right? So when I write  $r_R$  what is the equation?

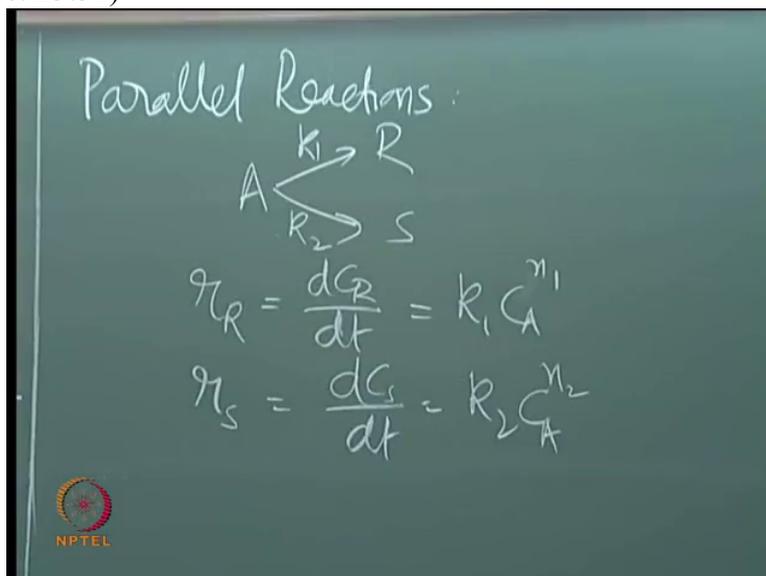
Yeah  $dC_R/dt$ , if I take you know with respect to this rate, then  $k_1 C_A$ , here Ok just for discussion sake I am not taking initially  $n$  equal to 1, but some value  $n$ , Ok. Yeah. So then

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r S equal to d C S by d t which is k 2 C A, this is n 2,

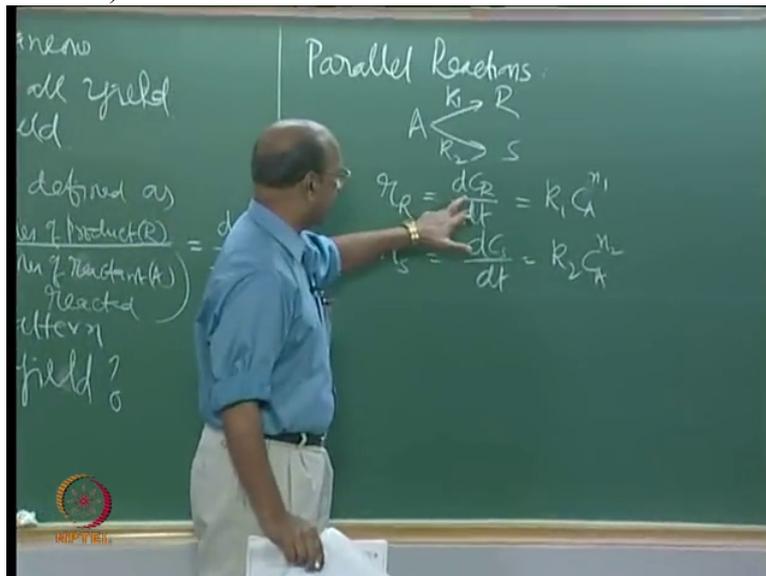
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Ok. Yeah.

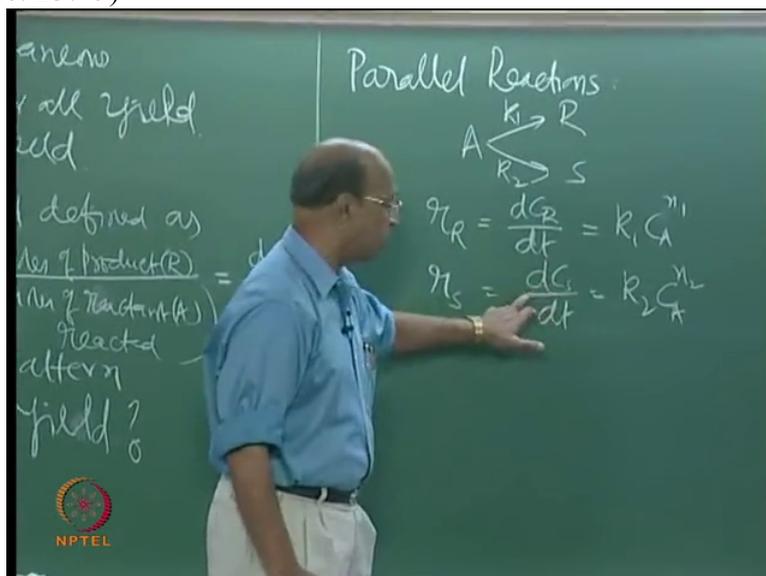
Even though we have told about yield and all that, to discuss what kind of contacting pattern you get, Ok, the arguments will be same. So what I want to do is I will take

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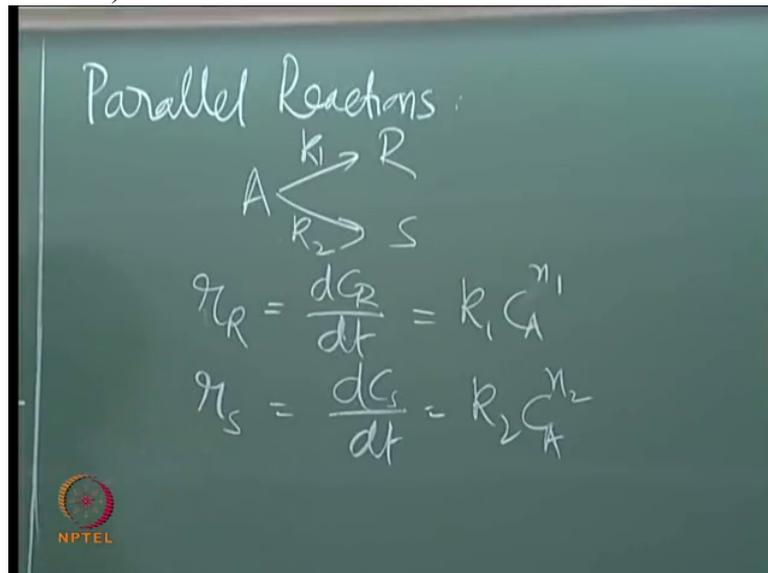
d C R by

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d C S, d t, that means I can take the ratio of r R, r S so which means that this ratio should be maximum. That means r S should be

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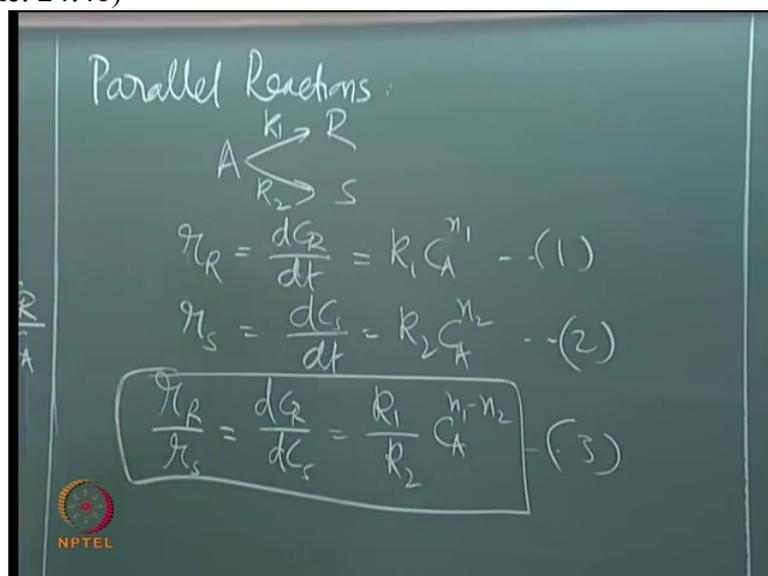


minimum. That is all.

I think you know that same argument even if you write in terms of yield also you will get the same conditions only. That will not change. But this will give direct, straight forward answer. So that is why we are taking only for explanation. Good.

So now, 1, 2, then if I write  $r_R$  by  $r_S$  which is nothing but  $dC_R$  by  $dC_S$  again which is nothing but  $k_1$  by  $k_2$ ,  $C_A$  to the power of  $n_2$ , Ok. This is equation 3. Now let us discuss this equation. Our idea is to maximize this, so that I will get the maximum R.

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Ok.

So what are the variables with me to do this? But you know

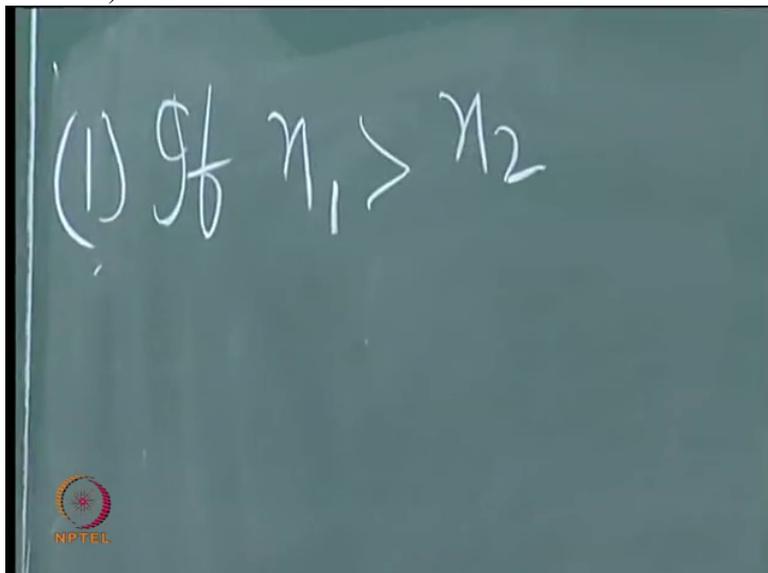
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we do not have, luckily; unfortunately we are not the dictators of what is  $n_1$ , what is  $n_2$ , right? That is nature of those reactions. So we cannot do anything.

So that is the reason why what we will try to do is that let us take, in the first case, case , if  $n_1$  is greater than  $n_2$ , right, case 1.

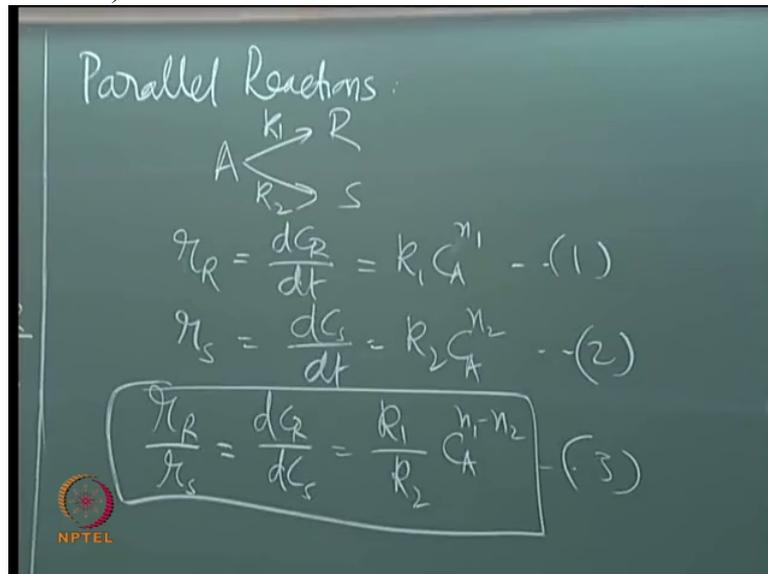
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Ok what will happen? Because I want to maximize that, if  $n_1$  is greater than  $n_2$ , for the present let us assume that we have isothermal system, Ok, temperature. That means  $k$  value I do not have again choice, Ok. Because let us understand each at one time, Ok.

So when  $k_1$ ,

(Refer Slide Time: 25:38)



that means  $k_1$ ,  $k_2$  constant there under these conditions and then you have  $n_1$  greater than  $n_2$  means

(Professor – student conversation starts)

Student:  $C_A$  greater than

Professor:  $C_A$  should be

Student: greater than

Student: more,  $R$  is more

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Student: P F R

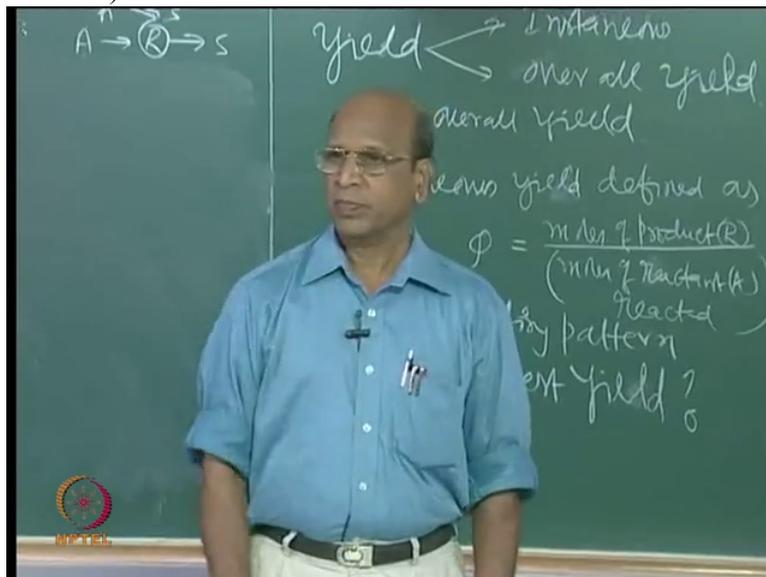
Professor: How is it increasing?

Student: Using P F R

Professor: n 1 is that but I think you know, that means the concentration of A is as much as possible, high, then you will get more

Student: R

(Refer Slide Time: 26:04)



Professor: Yield, Ok, more yield, more R. So that is the condition, right? So that means yeah, exactly so now we have to think which reactor will give me that kind of high concentrations when the reactors are introduced into the reactor?

Student: P F R

Professor: Why only P F R?

Student: P F R, Batch also will give.

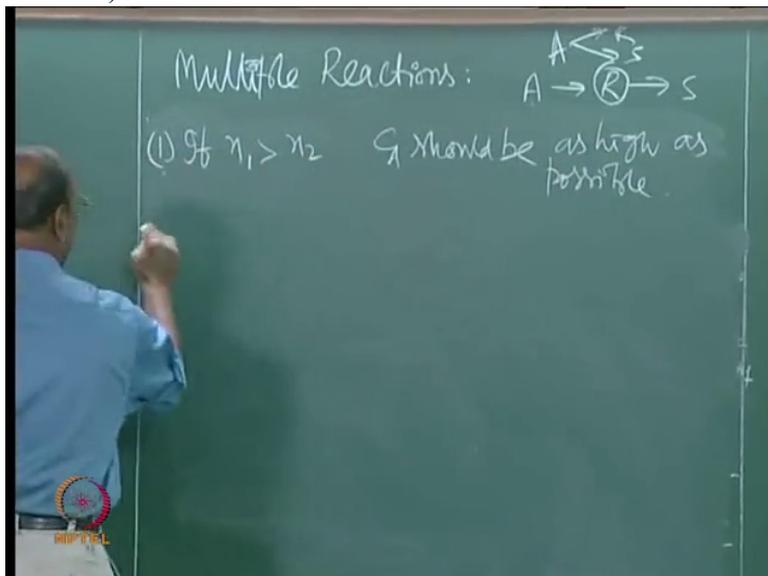
Professor: Batch also

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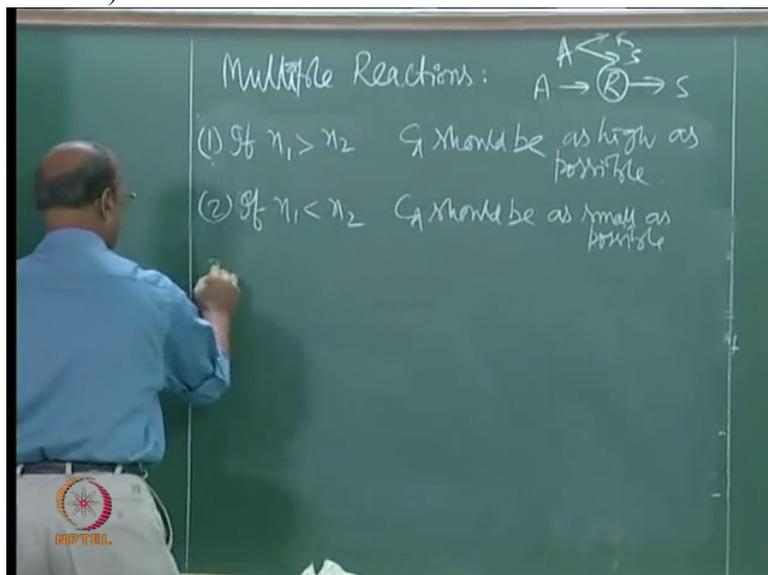
exactly gives you the same thing. So that is why, the general condition is  $C_A$  should be for this.  $C_A$  should be as high as possible. That is the one, Ok. So then if 2,

(Refer Slide Time: 26:46)



if  $n_1$  is less than  $n_2$ ? The reverse of that definitely. So  $C_A$  should be as small as possible. Ok. Then

(Refer Slide Time: 27:11)



the other alternative is, if  $n_1$  equal to  $n_2$ , then yeah, no what you want to say in terms of

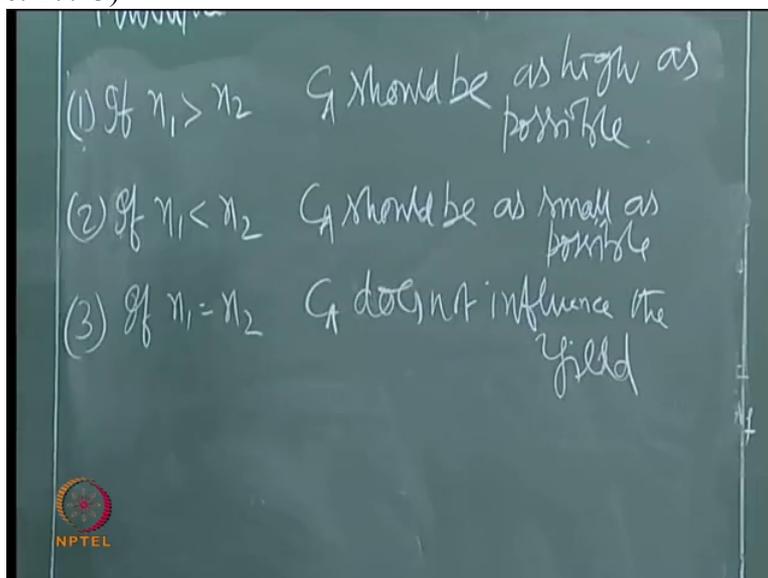
Student: 0:27:23.9 order

Professor: Concentration? Independent of  $C_A$

Student: Independent of  $C_A$

Professor: Ok, yeah.  $C_A$  does not influence the yield. Ok, good.

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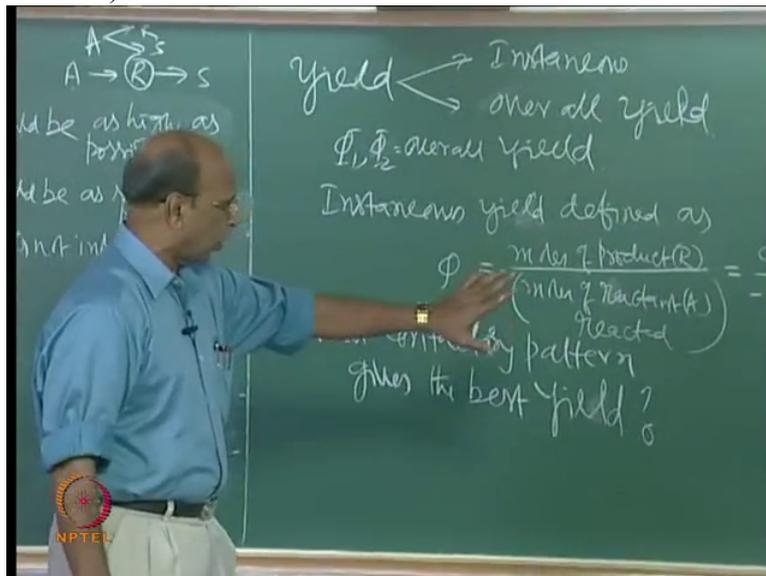


Then what influences?

(Professor – student conversation ends)

Now  $k_1$  and  $k_2$ , right. So in general,  $k_1$  and  $k_2$  only

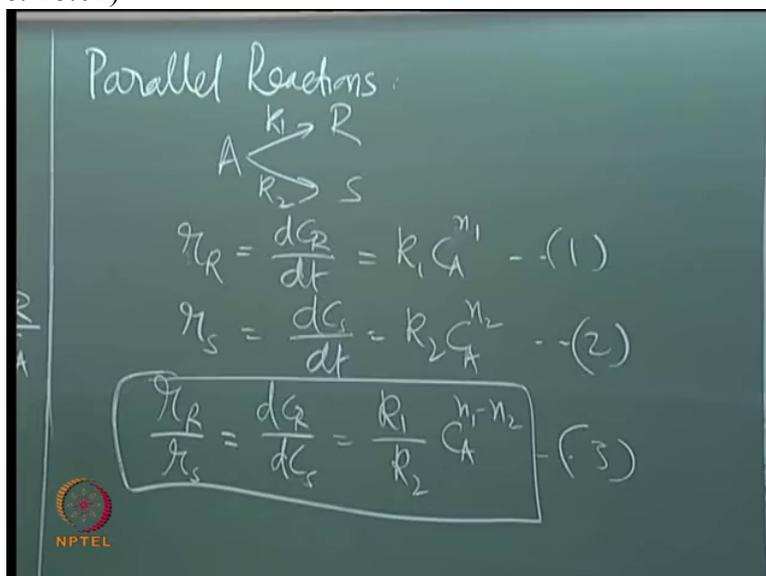
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what we have. That means when you are talking about  $k_1, k_2$  changing, so you have now temperature coming into picture, right? That is the second alternative.

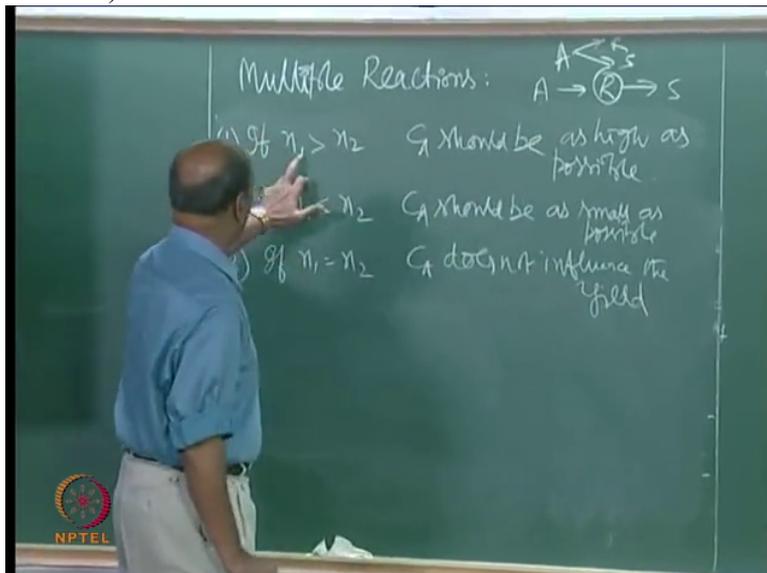
So that means of course,

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even, even here also I should be able to say now,

(Refer Slide Time: 28:06)



$n_1$  greater than  $n_2$ , and I have two constants, what is the parameter which can characterize the reaction? Temperature is one, but other than that what are the variables you have in this equation  $k_1$ ?

(Professor – student conversation starts)

Student: Activation energy

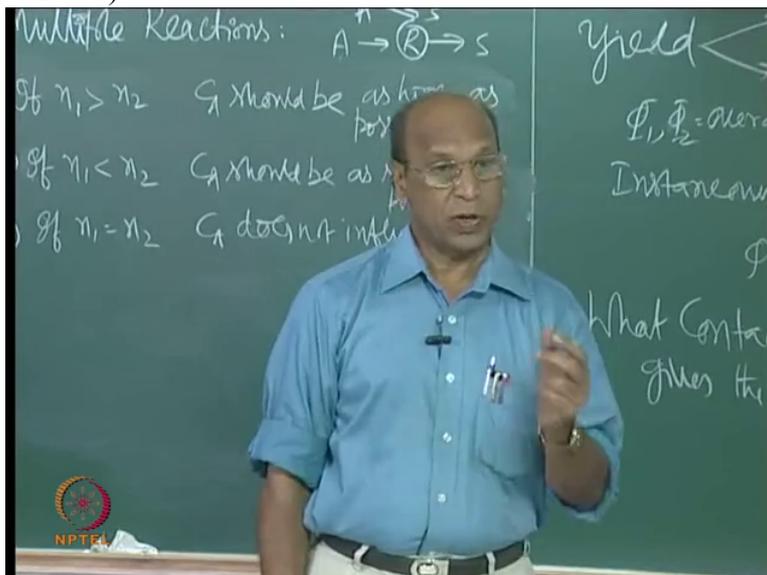
Professor: Activation energy. Ok,

(Refer Slide Time: 28:25)



that means you also learnt this if I have high activation energy;

(Refer Slide Time: 28:30)



will it favor reactions at high temperature?

Student: Low temperature

Student: E should be low.

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E should be low, so that reaction will take place quickly

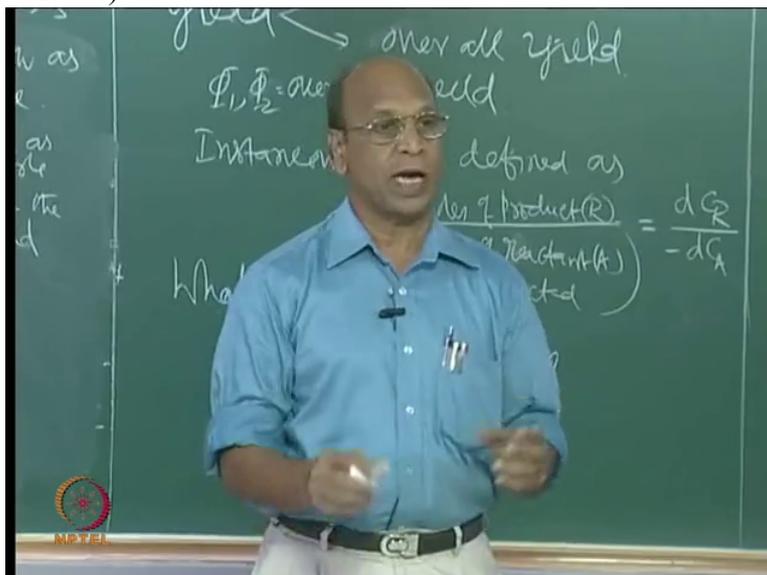
Student: Less than

Professor: Yes?

Student: E should be low?

Professor: My question is

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if you have high activation energy, will it favor reactions at high temperature?

Student: Yes, yes

(Refer Slide Time: 28:53)

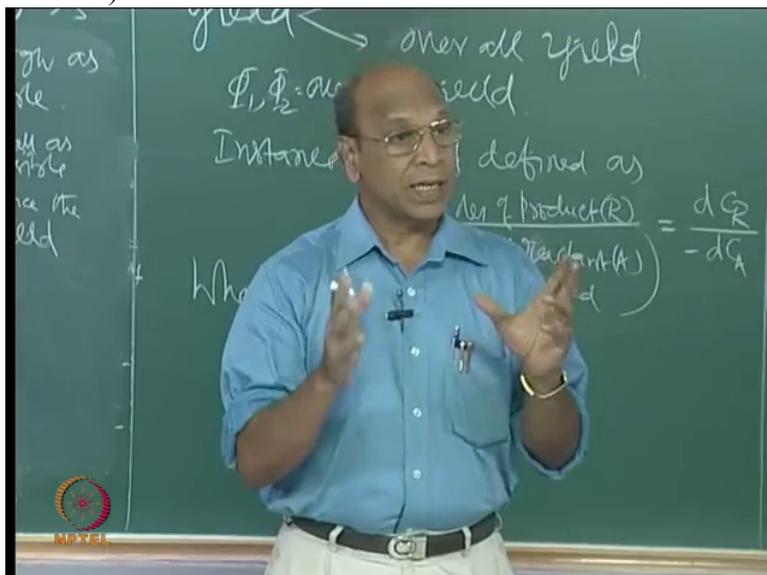


Professor: Why did you say earlier no, now yes?

Student: As the temperature increase, always the yield will increase.

Professor: You have to answer that also.

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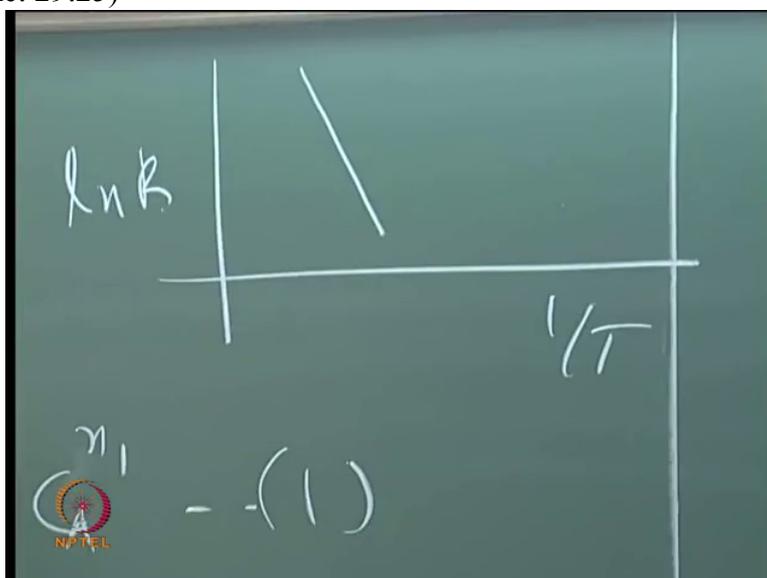
Please remember the diagram. What diagram?  $\ln k$  versus, excellent,  $\ln k$  versus,  $\ln k$  right?

Yeah so now if I have high activation energy what kind of slope I get?

Student: 0:29:21.7 like

Professor: Correct no.

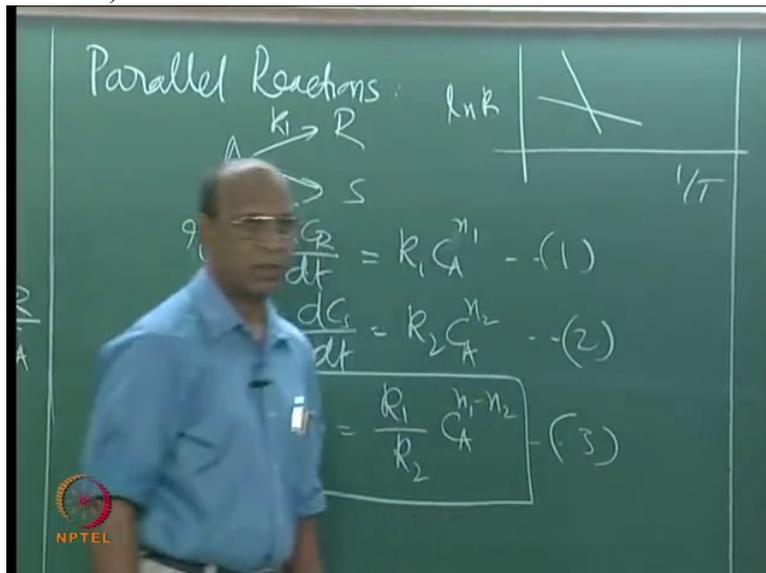
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If I have low activation energy?

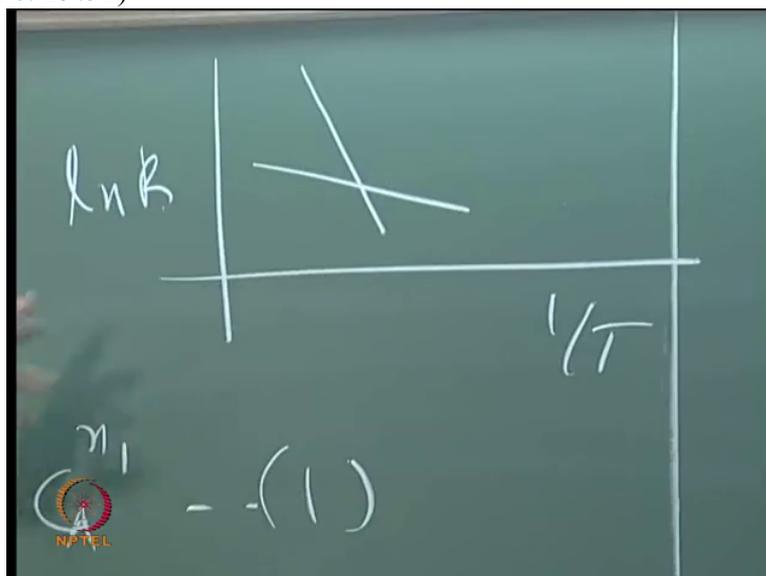
Student: Not like this.

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Professor: So that means this is k value.

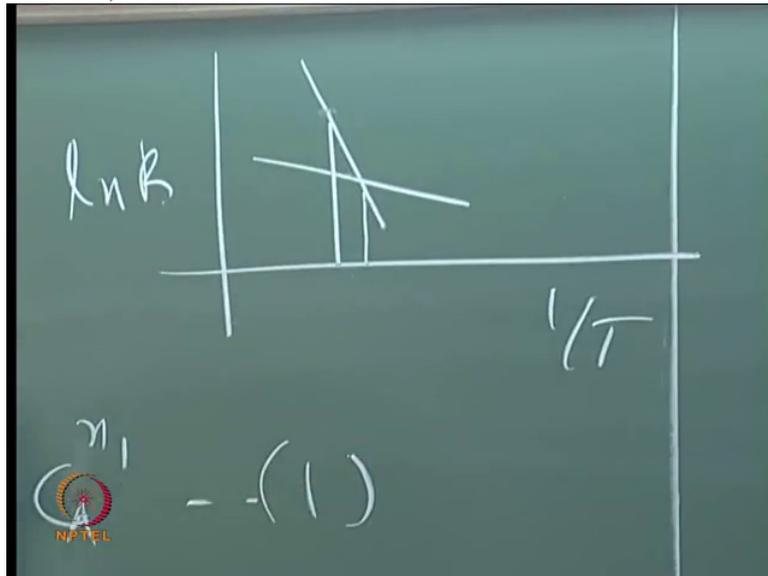
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(Professor – student conversation ends)

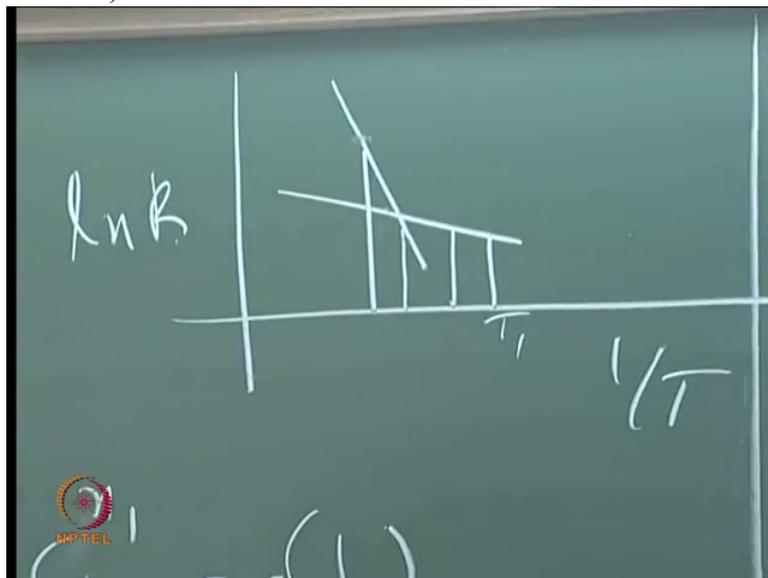
So if I talk about the temperatures over a small change I have tremendous change there with temperature.

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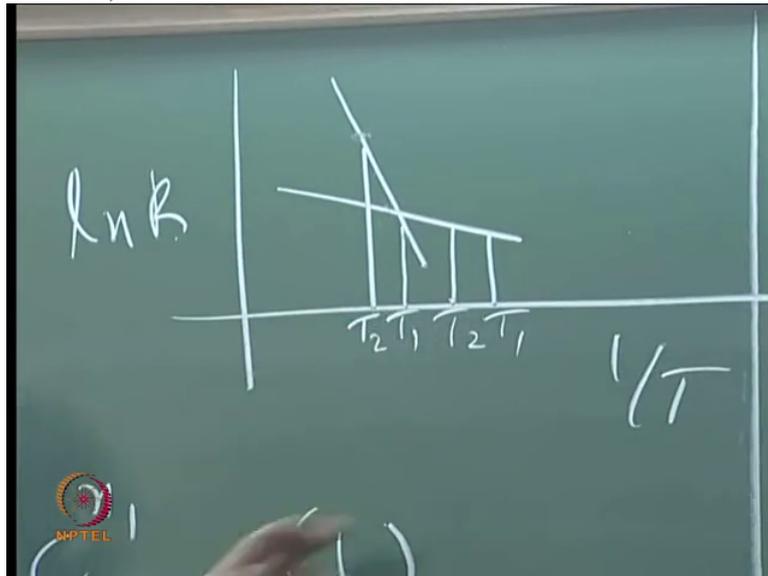
Whereas here, over a small change. I do not have that kind of, you know this is  $T_1$  corresponding to  $1/T_1$ ,

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Ok,  $T_2$ , this is also  $T_1$ ,  $T_2$ ,

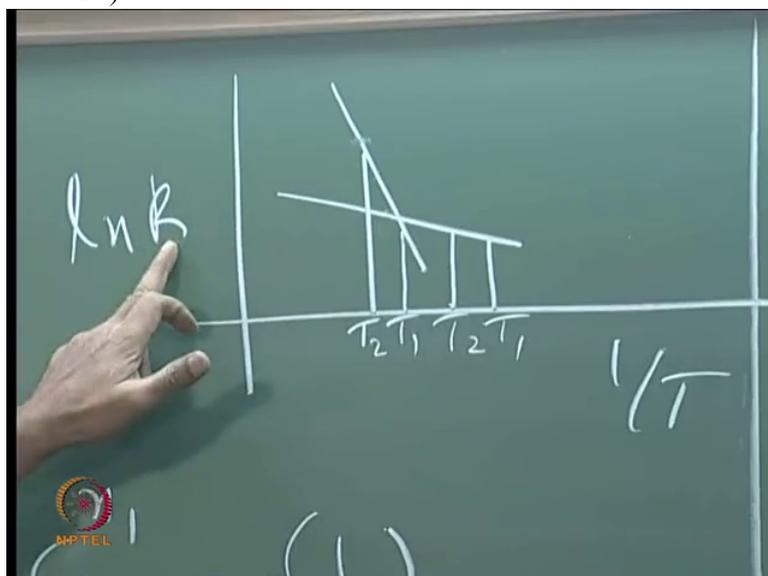
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please do not get confused. This is corresponding to  $1/T_1$   $1/T_2$ , right, that scale, right.

So that is why this if you remember you do not make the mistake. When it is too steep a slope, then a small change in the temperature will increase the rate of reaction. Why,  $k$  is increasing.

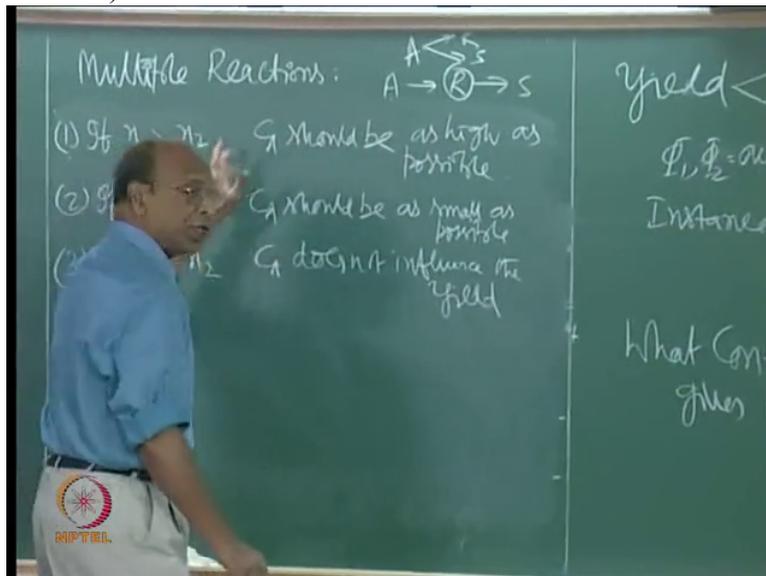
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When  $k$  increases it is minus  $r_A$  equal to  $k$  into  $C_A$   $e$  to the power  $C_A$  square or something, so when  $k$  is very, very large with slight temperature.

So that is why now you have to also add that other term,  $E_1$  and

(Refer Slide Time: 30:27)



E 2. So depending on what is E 1 and E 2, we have to also discuss whether the temperatures depending on, what kind of temperatures you maintain? You would have chosen for this case  $n_1$  greater than  $n_2$ , plug flow reactor or batch reactor, right.

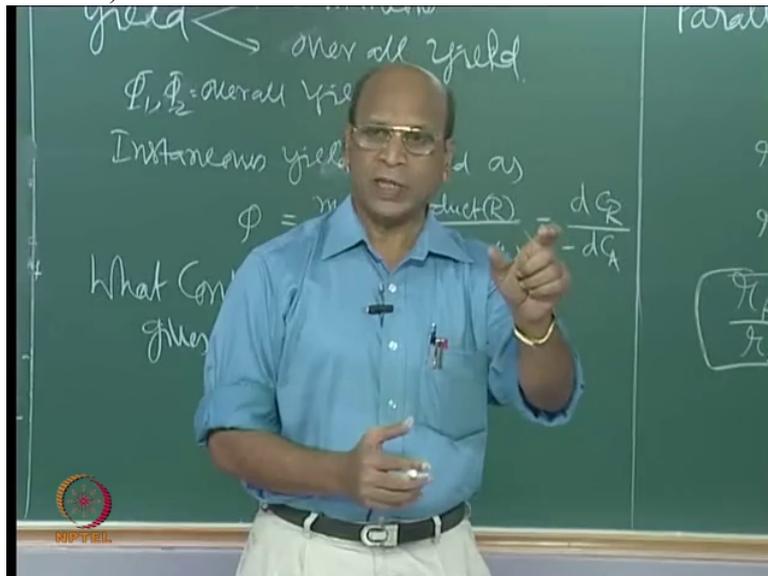
So once you have that system, now you are not satisfied with that. You want to increase further the yield. What do you do? You look at

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the activation energies. So depending on activation energies,

(Refer Slide Time: 30:59)



now if the activation energy of first reaction is let us say, greater than second reaction, then maintain high temperature. You see the rules?

These are the beautiful rules. And these rules are same for almost all the cases generally  $n$  greater than zero. Ok, we are talking of only  $n$  greater than zero. So that is how you now bring the temperature and also concentration and then try to choose the best reactor. One is concentration choosing will depend on what kind of reactor you are choosing. High concentration means normally it is plug flow

(Professor – student conversation starts)

Student: R will be formed, S will also be formed.

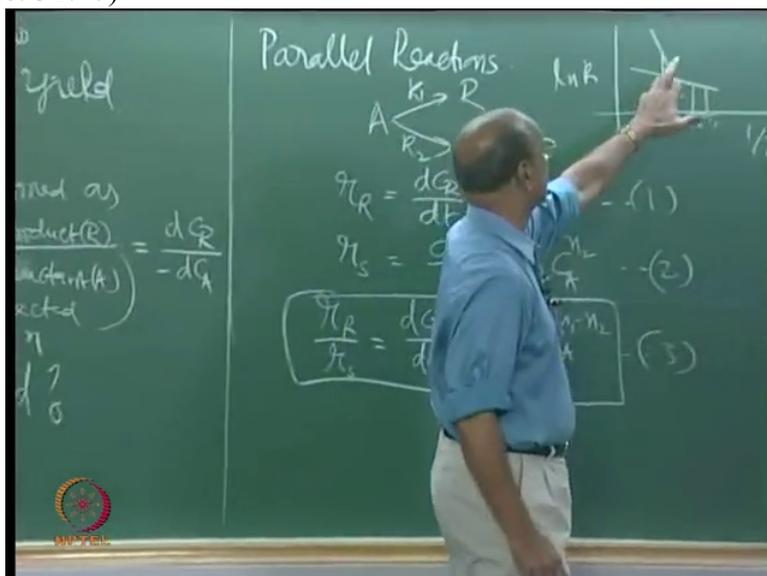
Professor: Yes, but the change in S is smaller than the change in

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R, why? Activation energy again. The same thing.

(Refer Slide Time: 31:47)



The rate of formation of R is much high than the rate of S. Definitely it will increase. Ok.

(Professor – student conversation ends)

But how much it is increasing and whether your desired product is getting increased much more than the other product, right. So that is why there is a beautiful site, I do not remember exactly now, attainable regions.

If you go to Google, always you are in the Google only. So I think now next time when you are in the Google, you just type attainable regions, a t t a i n a b l e, attainable regions, this

site was started by some South African University. I think you know they are doing wonderful work particularly for multiple reactions.

Attainable regions means what is the maximum yields I can get by using various kinds of reactors for the same reaction. You know till some value of concentration, one reactor, beyond that another reactor. I may add this parallelly or I may, I am talking of reactors, Ok.

I have the given scheme of one reaction, right, given scheme of reaction. May be Denbigh scheme for example, right. So that means A going to R, R going to S and also A going to something else and also R going to something else. So my desired product is R.

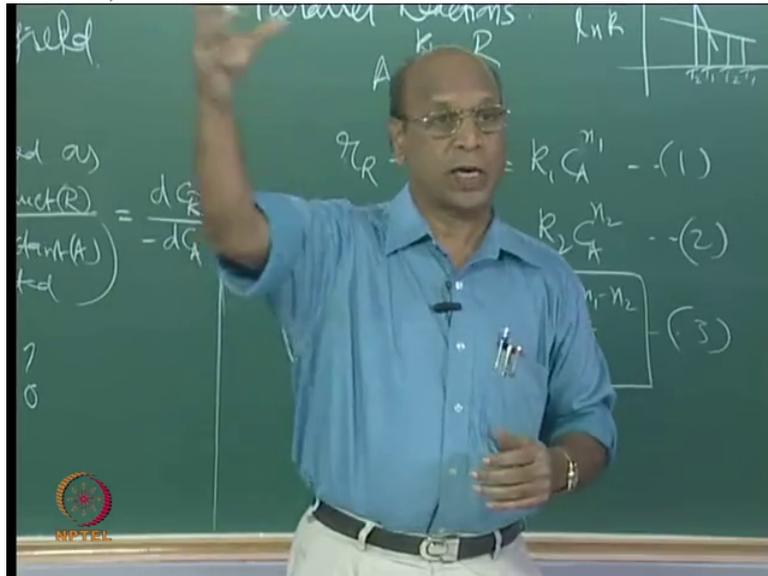
So by using any combination of reactors, that scheme is given to me, I am not talking about any more multiple reactions, I have one multiple reaction,

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complicated one. Now By using any combination of reactors, either parallel, series, may be till concentration 10 percent, one reactor, 10 to 20 percent another reactor, I am just telling no, all possibilities. And may be 30 to 40,

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another reactor, different combinations, all these combinations, maximum R how can you get?

You will see that if you have this kind of, you know in the site if you go through, you will see many, many rules there also. That is why in industry most of the time it is multiple reaction. In fact all academicians are cheating you by giving only simple example, right, most of the time.

Because otherwise if I give you Denbigh reaction and ask you to solve in quiz, you need 10 days. Ok, but 10 days quiz I cannot have, no. So that is why I think these you know these open problems and all that, sometimes we give, the assignments and all that we give. But what we teach here is the concepts where whether you use Denbigh reaction or Denbigh's grandfather reaction no problem, the rules are same.

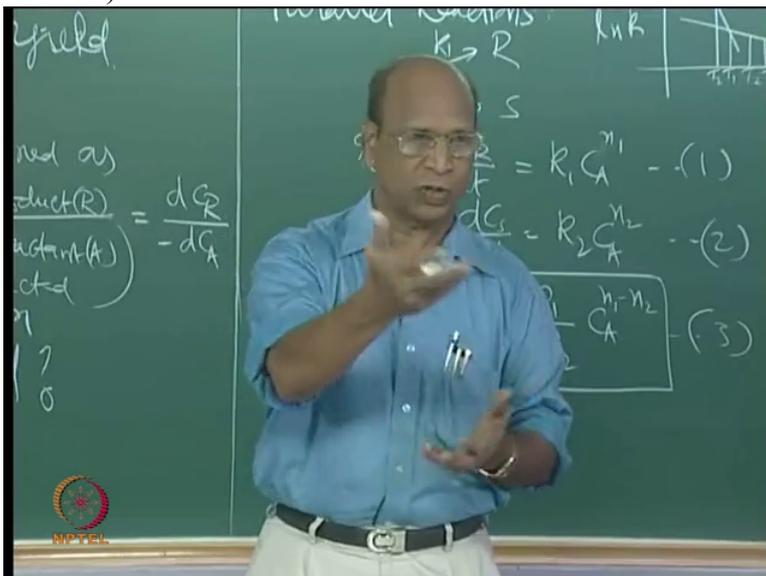
Ok, so that is absolutely there is no problem. That is the reason, you know why, all acad/academicians, I told also no, academic institutions always try to unify the knowledge. I told you I think already. I do not expect whatever I tell you, you remember also, Ok. So that is why I am repeating many times. So what did I tell, Sushmita? About, yeah, university always would like to have,

(Refer Slide Time: 34:48)



that is why name of the academic institution,

(Refer Slide Time: 34:51)



university, name itself is there. You are unifying many things. Ok. Whereas industry always thrives on

(Professor – student conversation starts)

Student: Diversity

Professor: Diversity, differences, Ok. So see if industrialist sits before periodic table, he will get confused. He does not know what to do. But if you tell in one column, let us say Ok, between may be chlorine and you have no, what are those things?

Student: Halogen

Student: Chlorine, fluorine, bromine, iodine

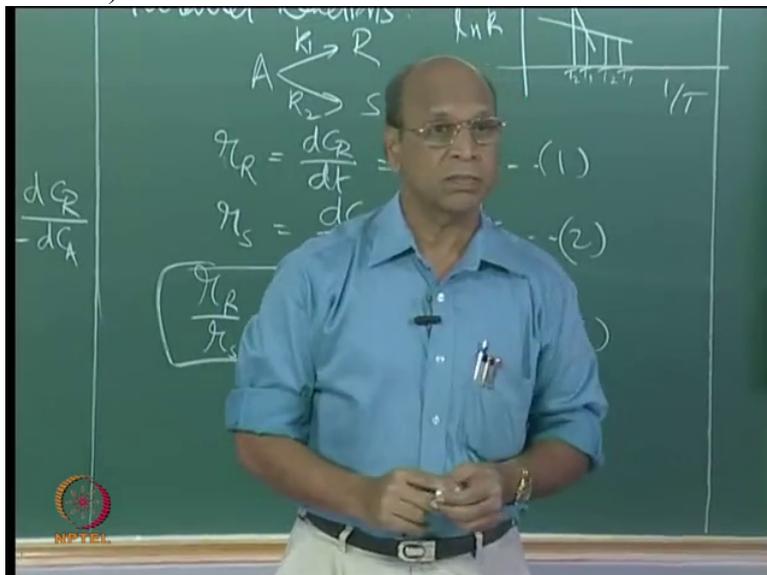
Professor: Yeah,

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so there is someone who says that iodine has excellent market.

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Then he will never look any other element, only at I 2, iodine. Because that gives him more money. Ok.

(Professor – student conversation ends)

But if you ask the Professor to sit before the periodic table, Oh 103 elements, how can you make all 103 look like as one element? You know, by unifying the properties of all these in terms of only 1 quality. That means I do not have to remember 103. Wonderful no?

So that is why you choose whether you want to become an industrialist or an academician. Academician means 103, 1. (laugh) and there 103 means 103, you have to remember and then see, Ok, iodine best. Tomorrow morning someone tells, no, no, no do not go to iodine, go to some other you know, tell me some other compound?

(Professor – student conversation starts)

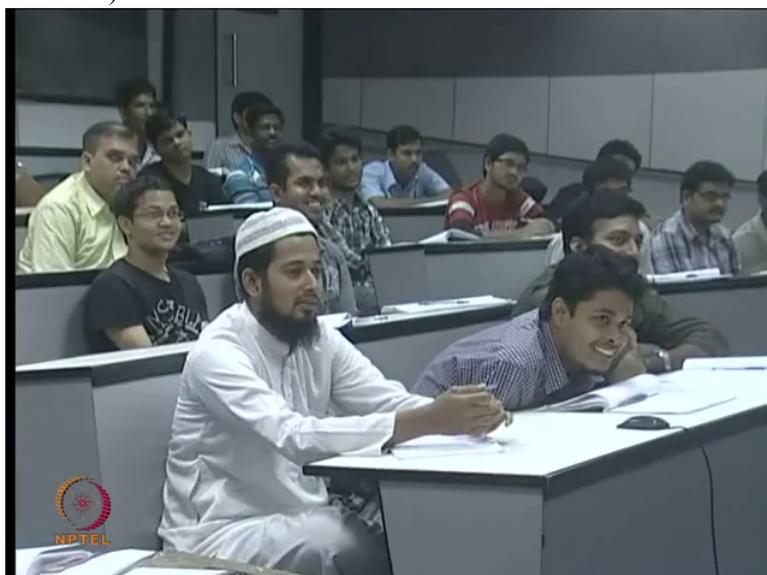
Student: Chlorine

Professor: Chlorine is same thing. I think some other element.

Student: Hydrogen

Professor: Why I say hydrogen?

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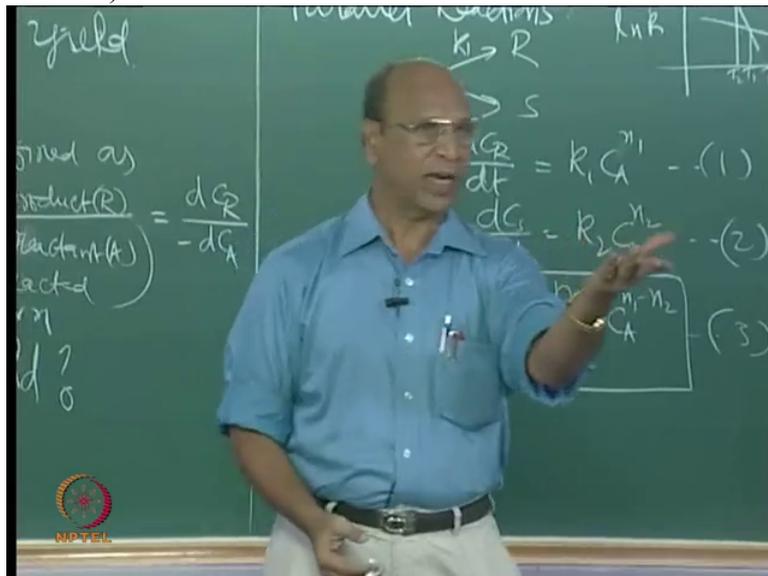


Everyone?

Student: (laugh)

Professor: Hydrogen production,

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no, hydrogen production on this planet, so much research is going on in terms of hydrogen production and how do you store, how do you transport, all these things are big problems.

(Professor – student conversation ends)

Because we think that by producing more amount of hydrogen, we can solve the environmental problem. Because when you burn it, you do not get CO<sub>2</sub>, you get only water. It is very good for us. We do not have anyway water.

You produce water; collect somehow so that means each car will have a water tank, right, hydrogen tank and a water tank. So you can use hydrogen, go in the car, at the end you take water, drink and then (laugh), again come back. So that is the kind of thing.

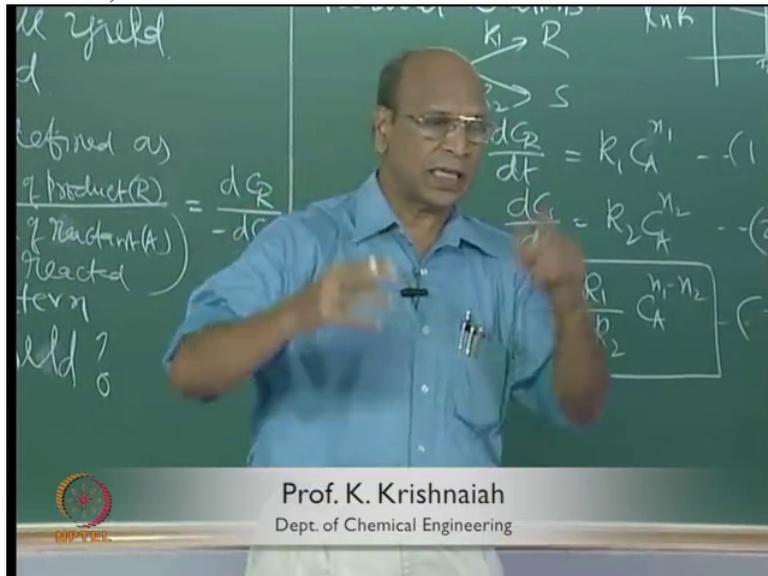
Hydrogen, tremendous amount of research is going on. So that is why industrialists always think of, Ok, now let me concentrate only on hydrogen.

Whereas this fellow, professor always thinks that, Ok hydrogen has only one element, one what is that, yeah electron and you know some other thing has got 23 electrons. I am interested more in 23, not in 1, what is there in 1, like that again he will try to bring that 23 in 1 and say that what is the commonality in this. Right.

So that is the reason why these rules are important for us to remember, right? So these two things please remember. When, if you have parallel reactions when  $n$  is large, try to maintain the concentrations as high as possible for the desired product.

And when the activation energy is very high, please remember that activation energy more means the rate of reaction

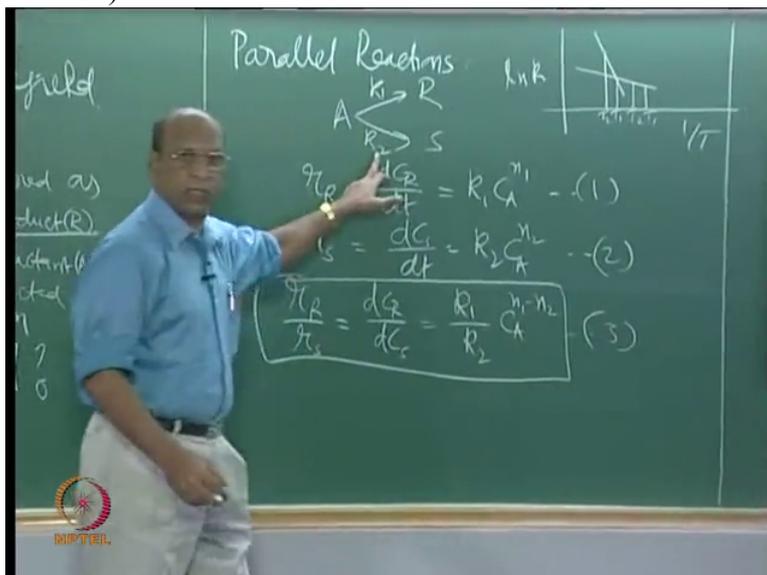
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will be very sensitive. The rate is very sensitive. If it is desired product what you want and the activation energy in the desired rate is more, then use high temperatures.

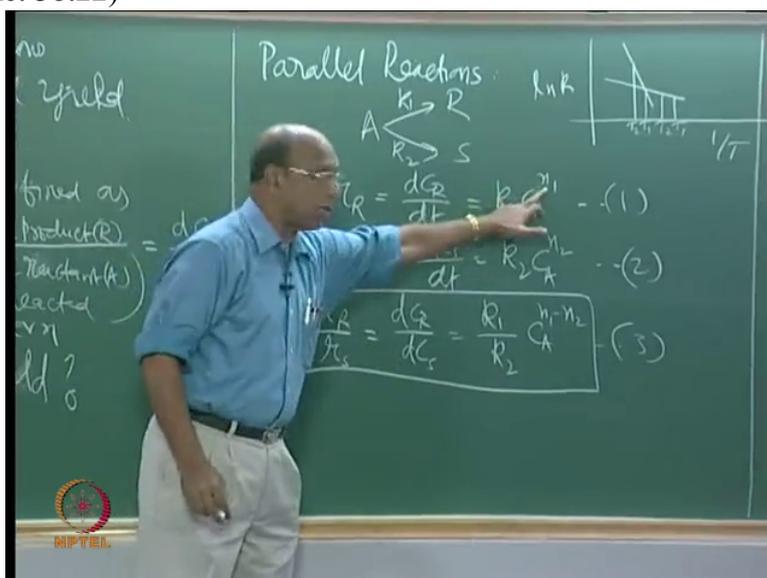
Otherwise in the same example, I have  $k_2$ .

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All these things, not our choices. Ok. You have to find out sincerely the kinetics. Kinetics means you shall have to find out

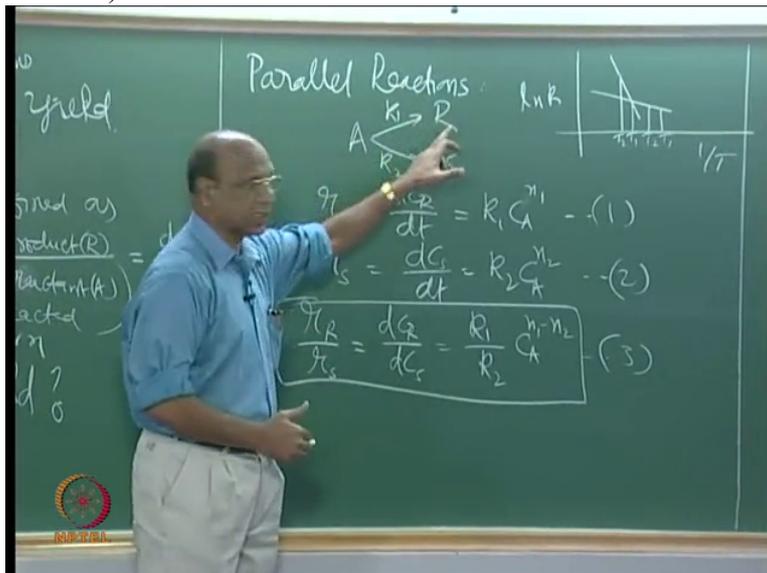
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order of reaction also also, no the activation energy here. Then that is the property of that reaction only.

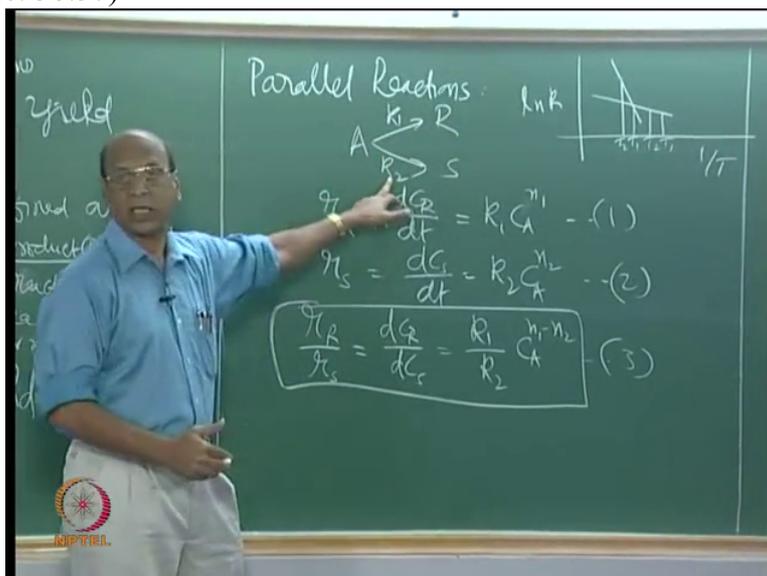
Because we do not have any choice there. I may like this reaction, this is R, my desired product

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but this fellow has more activation energy.

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Then what do you do?

(Professor – student conversation starts)

Student: 0:38:41.4

Professor: You have to use low temperature. Then again I think that Abhishek will ask that, Sir the temperature low means, you do not answer?

Student: (laugh)

Student: Converse is not true

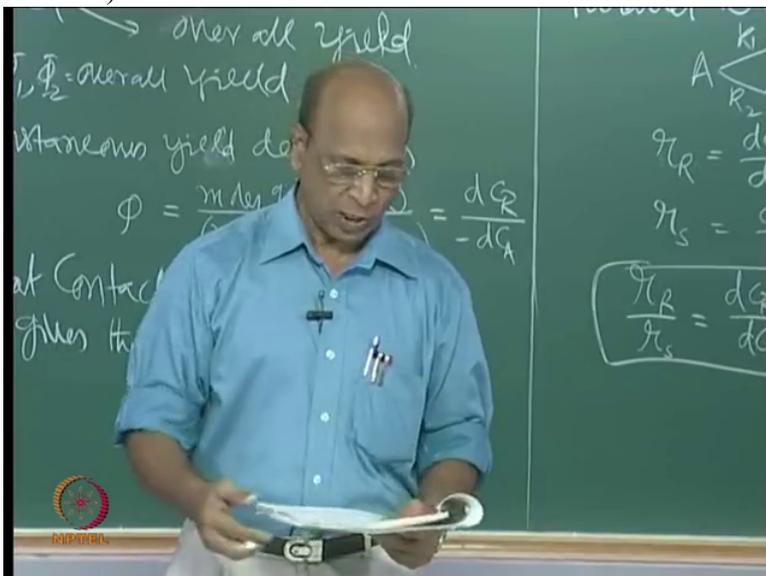
Professor: Converse is not true means you may say that, it is not the rate high, Ok. You may say that the rate is falling, what do you do? Yeah again there, when you compare, you know the production of R and then production of S, still production of R will be more.

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So that is how you have to manage. That is all the simple rules. And remaining is only mathematics. Tomorrow

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we have and Saturday I mean I thought I would complete this final reaction. So tomorrow morning and Saturday, this time we are meeting.

(Professor – student conversation ends)