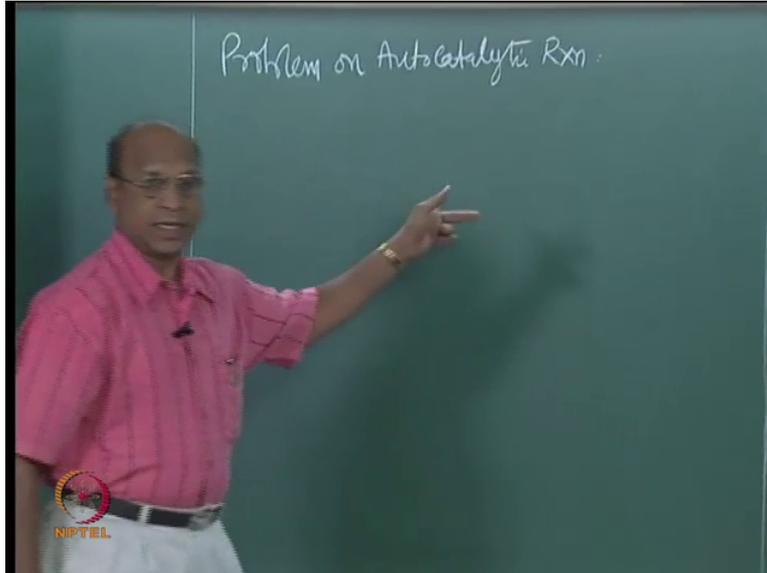**Chemical Reaction Engineering 1 (Homogeneous Reactors)**
Professor R. Krishnaiah
Department of Chemical Engineering
Indian Institute of Technology Madras
Lecture No 32
Multiple Reactions Part 1

(Refer Slide Time: 00:10)

Yeah, the other day I have given you this problem on autocatalytic reaction. Sushmita was asking you have not given the rate.
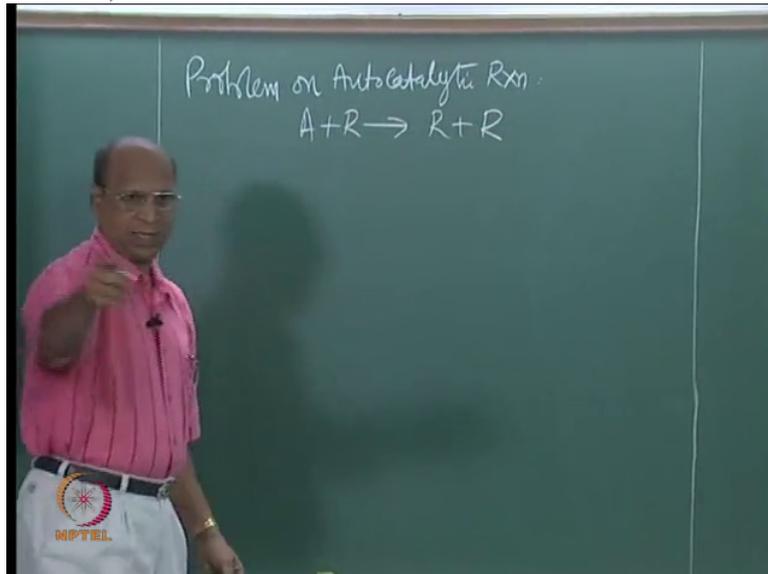
(Professor – student conversation starts)

Student: Rate I got it.

Professor: You got it, no? Yeah.

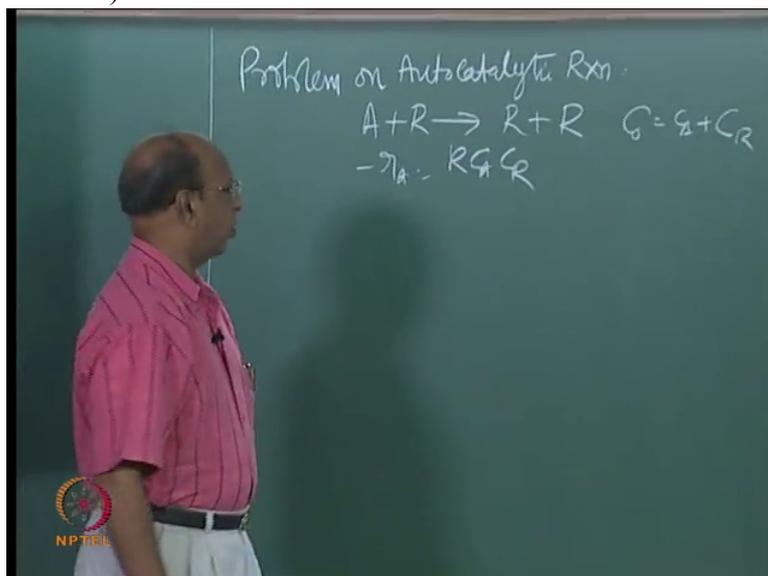(Professor – student conversation ends)

So for autocatalytic reaction, what is the, in the normal thing what
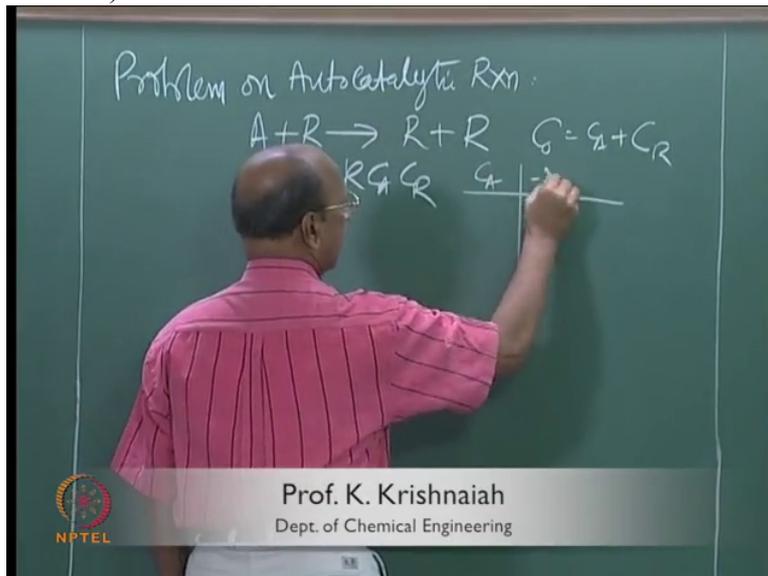
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is given there? Ok. It is elementary reaction that is given there. So minus r A equal to k C A C R. We also have a relationship here; C naught equal to C A plus C R, Ok.

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So what you want is a rate where 1 by minus r A versus, you can calculate C A minus r A
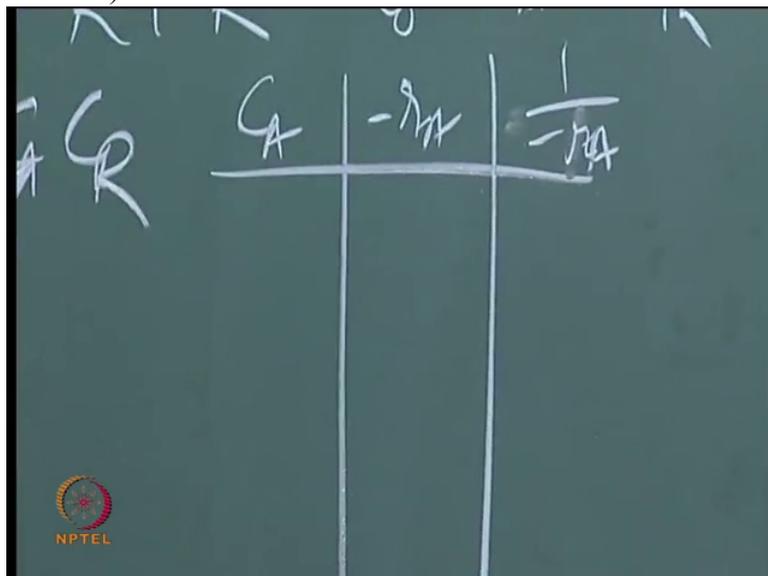
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and 1 by minus r A. You can also convert that into conversion if you want. But even

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without doing that also you can calculate.

So now you also know that C A naught

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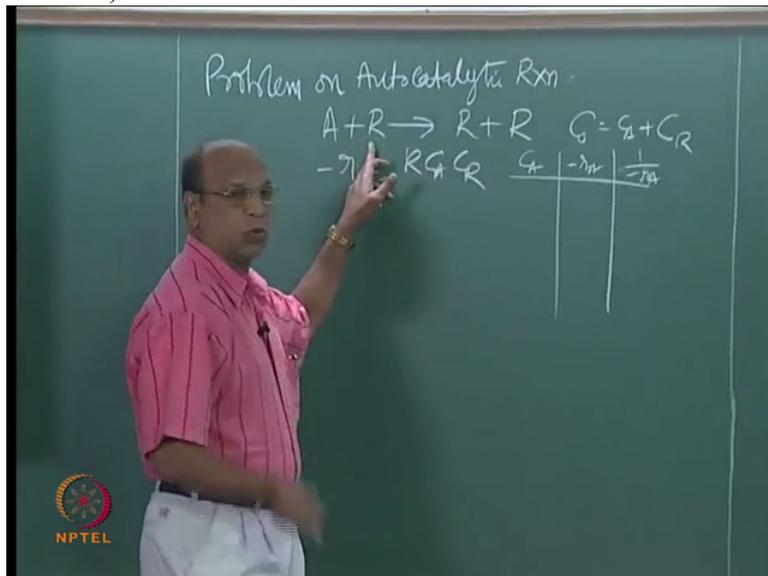
equal to 1, not C A naught, total.

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C naught equal to 1. So that means this is 1 minus C A equal to, yeah 1 minus C R. So now you can calculate what is C A, C R, what is C A,

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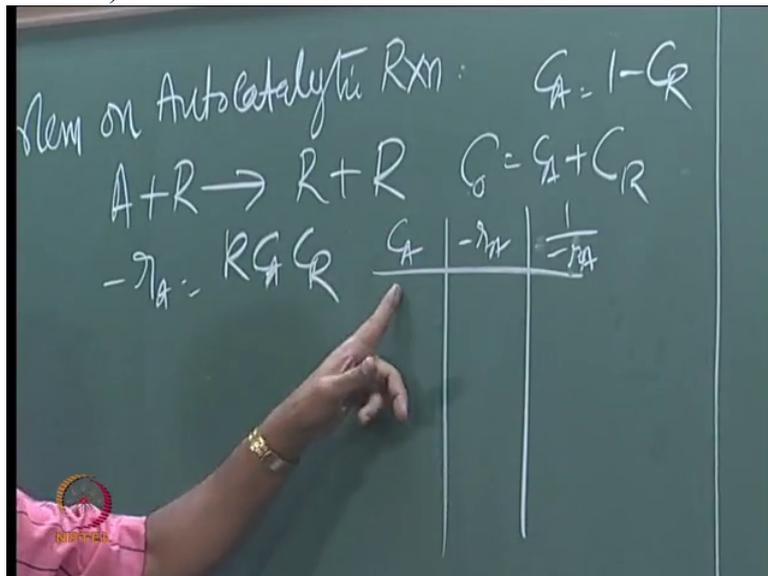
what is C R you can calculate? You can assume C A equal to point 9 9.

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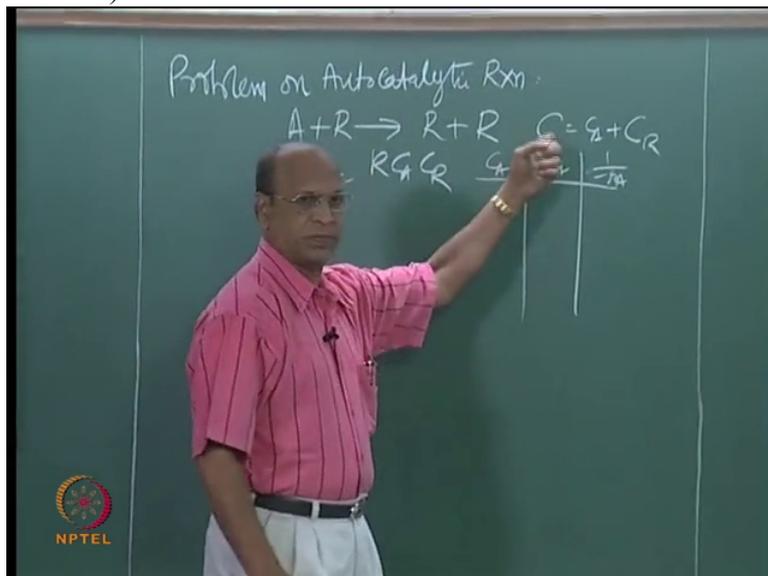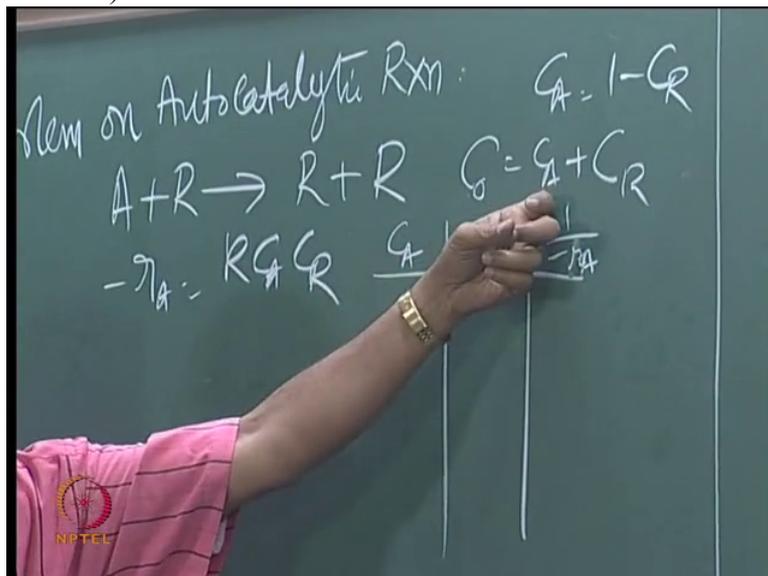Ok. C A equal to. No, point 9 9 it cannot be. Because C A naught itself is point 9 9.

So like that, you know point 9, point 8, point 6, point 7 and all that. Correspondingly you can calculate R and the rate is C A into C R. So you will get all the data.

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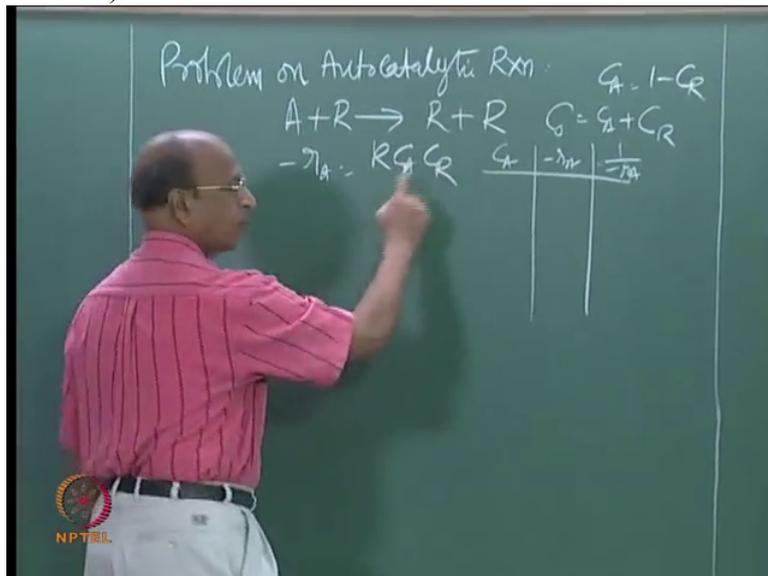
So once you get the data, now you plot. This is 1 by minus r A versus C A also you can plot. X A also you can plot, whatever is convenient to you, right?

So then you will also get here something like this.

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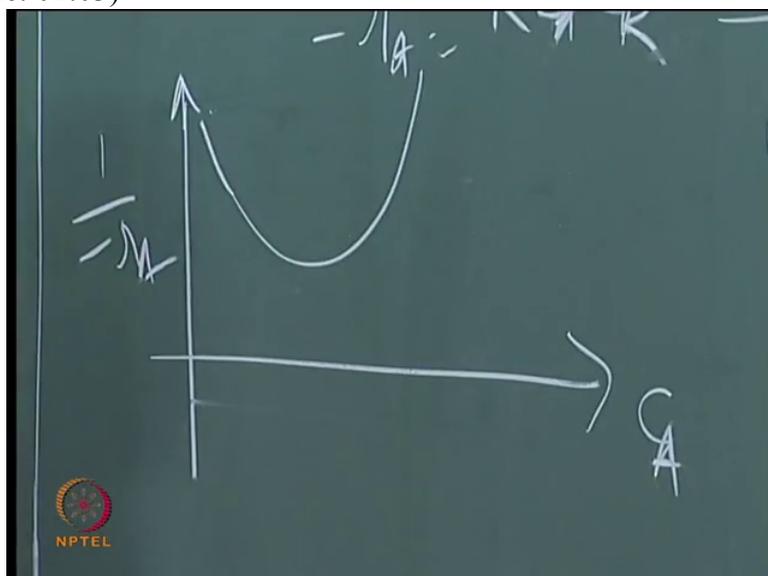
So you will have this C A C R, the product is maximum at one point, I think it may come around point 5 5 or something. Point 5, yeah you will get that maximum, so then you will have that maximum here corresponding C A, C A equal to point 5?

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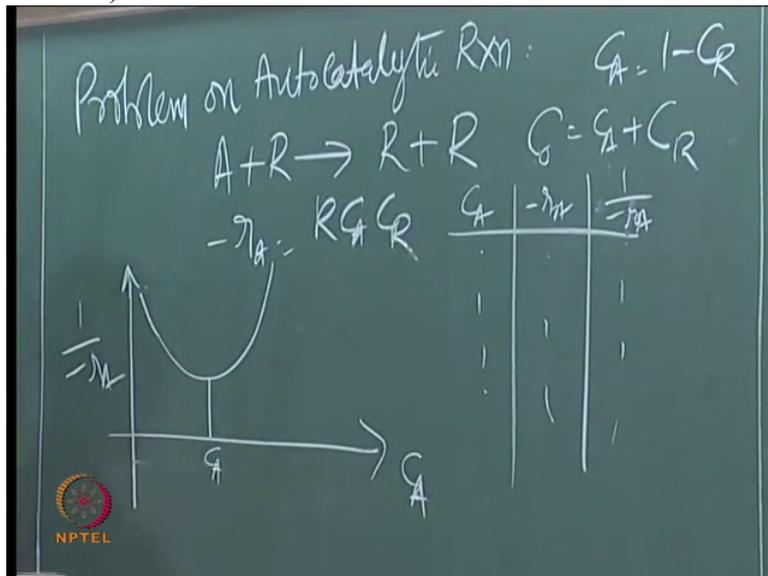
It may not be C A equal to exactly point 5.

(Professor – student conversation starts)

Student: You take point...

Professor: Where you get the maximum rate?

Student: C A equal to C R at that point we are getting

Professor: C A equal to C R, at that point because you have point 9 9 and point naught naught, may be the effect is not much.

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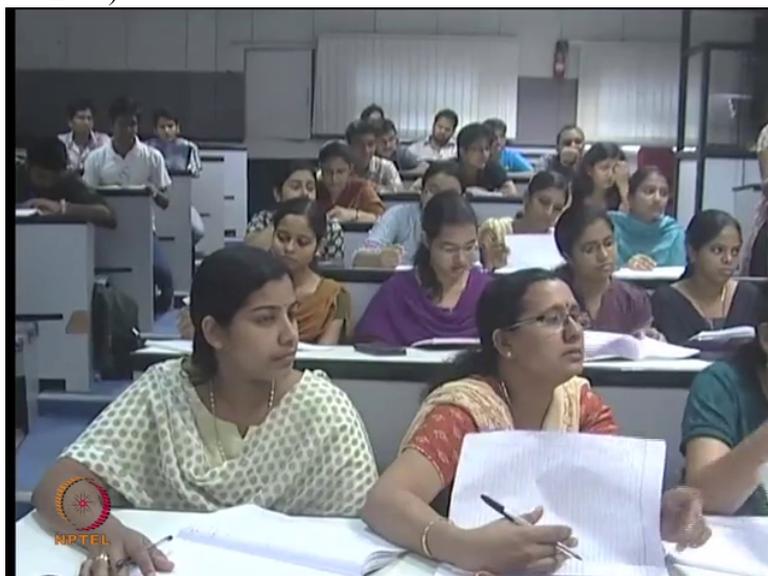
But actually that is not the one. Ok. You can also calculate

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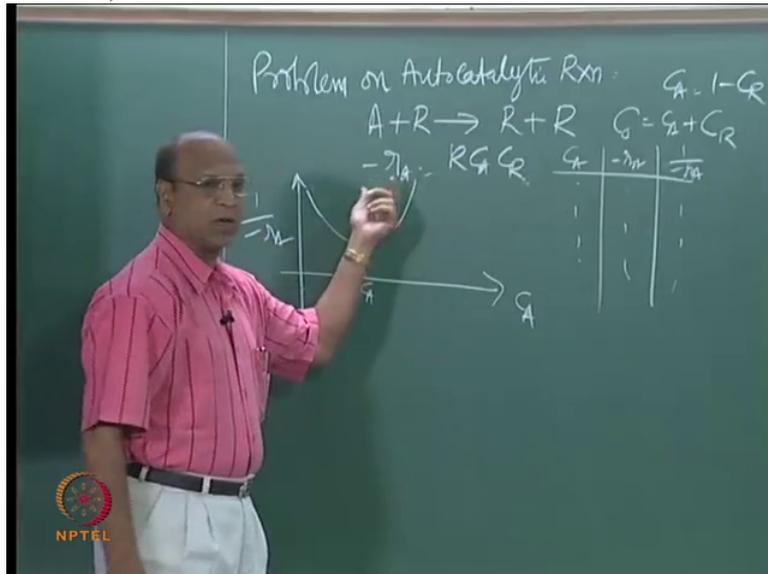
for example, when do you get that maximum. How do you get?

Student: Maximum when C A equal to

(Refer Slide Time: 02:44)

C R.

Professor: Yeah. This is d C A

Student: Where total concentration is 1

Professor: This is d C A by d t

Student: Yeah, d C A by d R
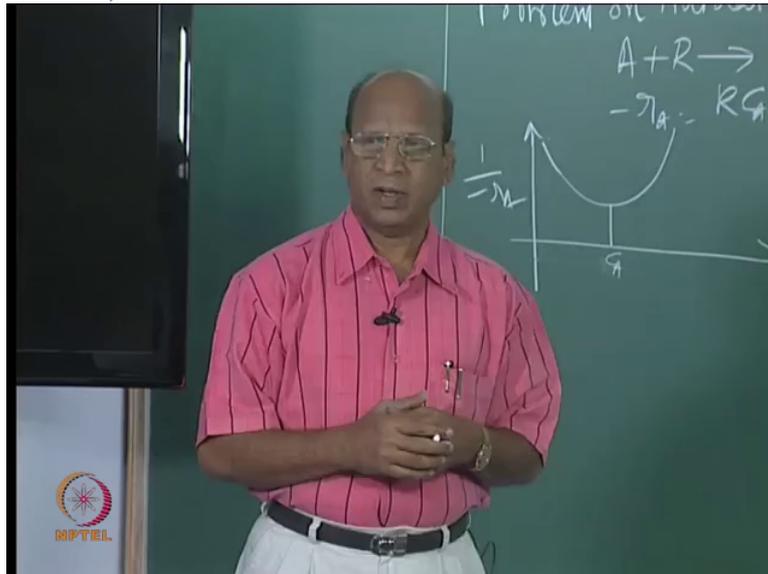
Professor: Rate is maximum we are telling. Rate is a function. This is what I have been telling you

Student: d R A by d C A equal to zero

Professor: Yeah, this is what you know the simple calculus we are not able to use and here in C R E; at this level only those simple calculus.

(Professor – student conversation ends)

See most of the time, area under the curves and d y by d x, or you know second derivative also we do not go most of the time, right? Yeah. So d of minus r A by d C A equal to zero, if you do you can actually find out, yeah, Ok.

So then that is C A equal to point 5, right? Yeah.

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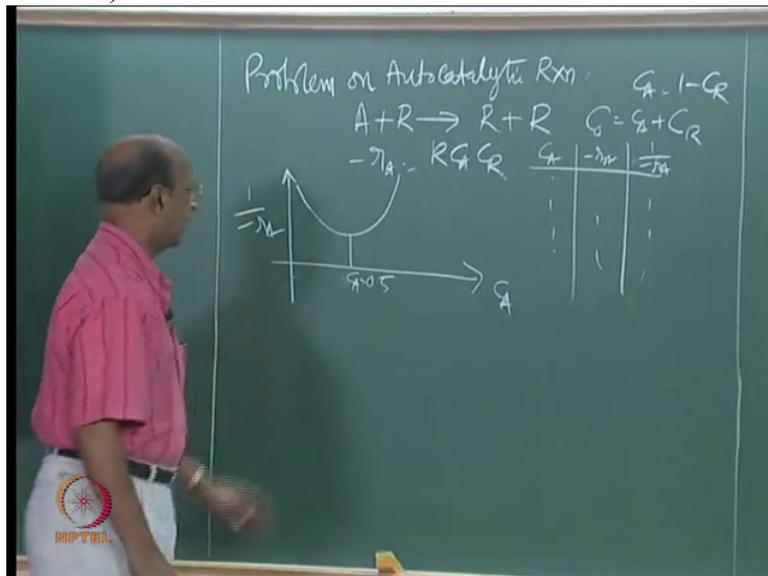
So then now the problem is I think 90 percent conversion no, given? Yeah. So if I write C A must be point 1

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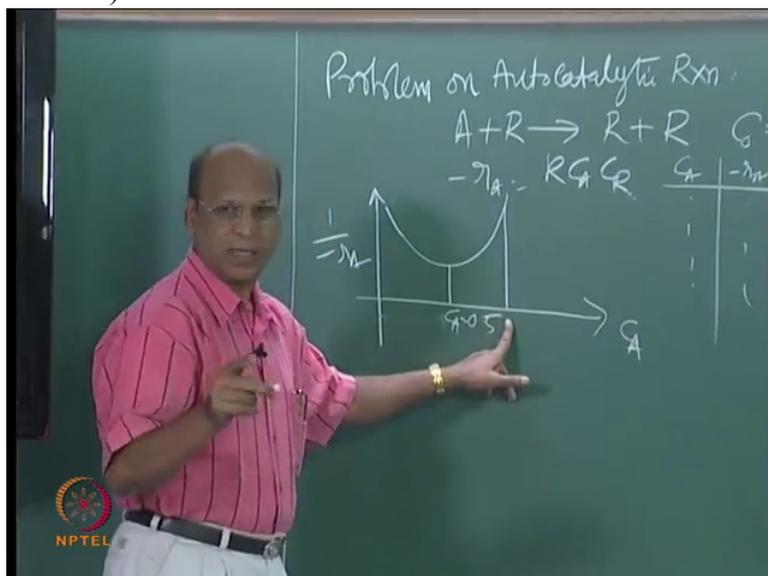
here, Ok, yeah, so that means somewhere here. This is C A naught, this side Ok because it is

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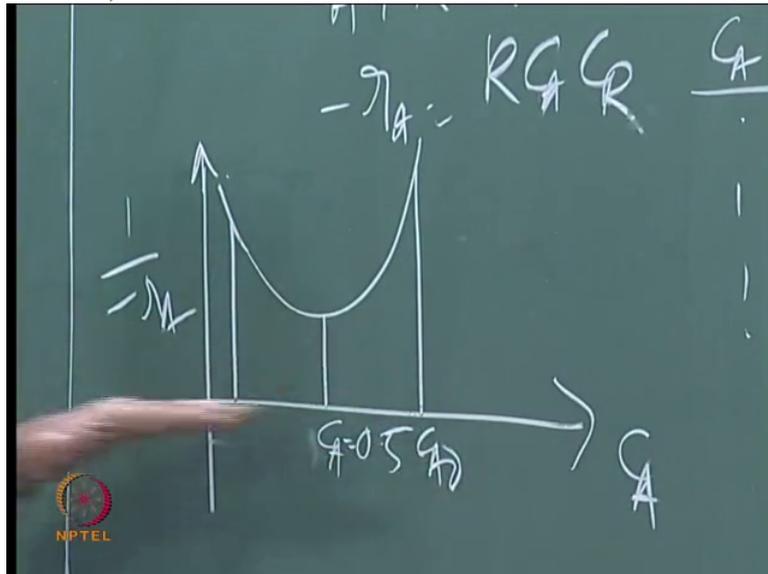
increasing. Here more and then here less no, this is zero almost. Ok.

So now all the problems can be solved if you plot this and then try to find out what is the tau. Volume is not asked. Only tau is given. So if it is only ideal, simple single mixed flow reactor what is the area you take? This much is the area. This is for M F R,

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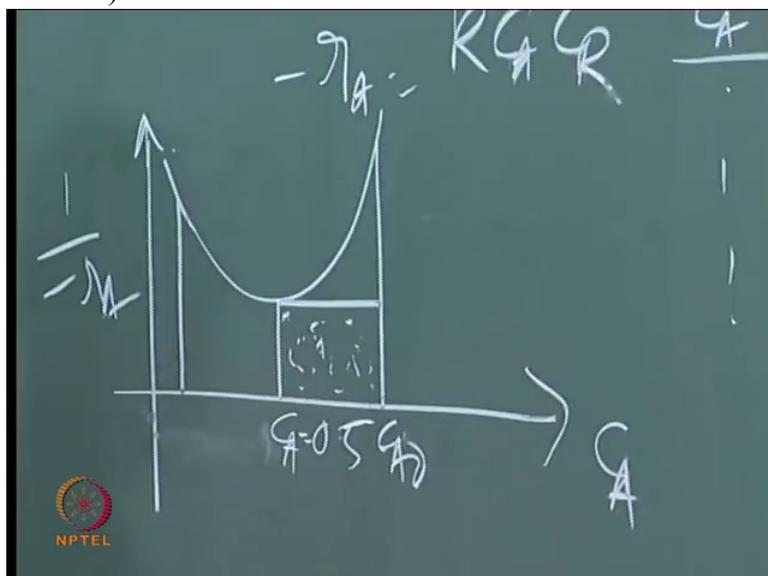
Ok.

And for P F R for 90 percent conversion? If this is 90 percent conversion? So this is point 1

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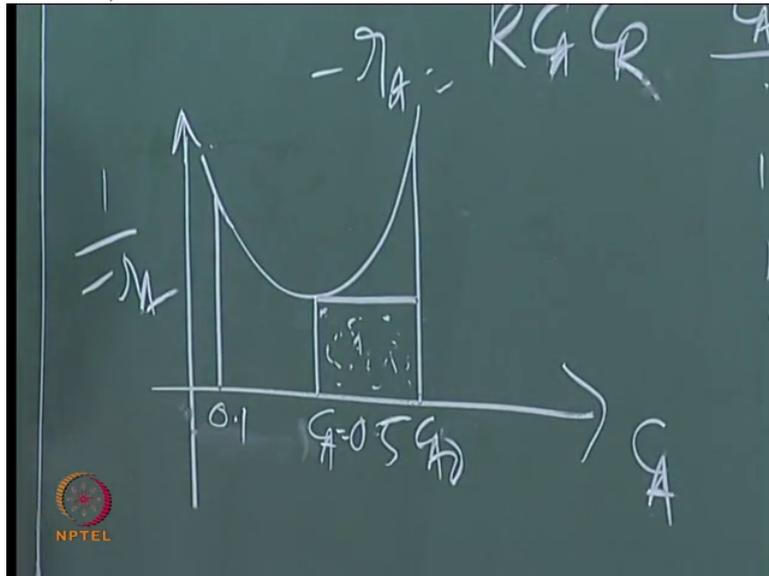
(Professor – student conversation starts)

Student: 90 percent

Professor: Yeah, this entire thing, Ok, yeah all that.

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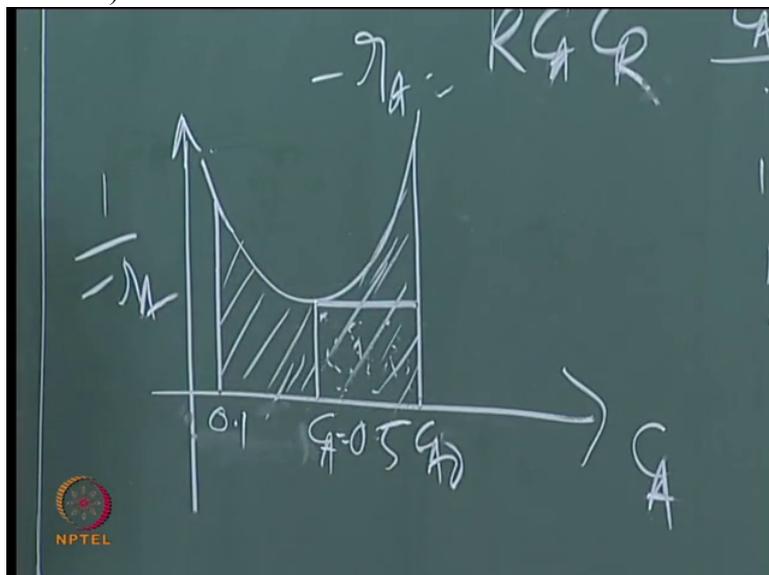
So like we already discussed. If I need two then I have to have till here,

(Refer Slide Time: 04:34)

Student: Mixed flow

Professor: Mixed flow and from here to here, plug flow. It is not

Student: 90 percent conversion

Professor: Yeah, because that point 1 is there, point naught 1 is there that is the reason.

Student: 0:04:44.0

Professor: Yeah whatever exactly calculate that.

(Refer Slide Time: 04:48)

Student: d R A is equal to

Professor: It is not, actually Abhishek it is not asked 90 percent.
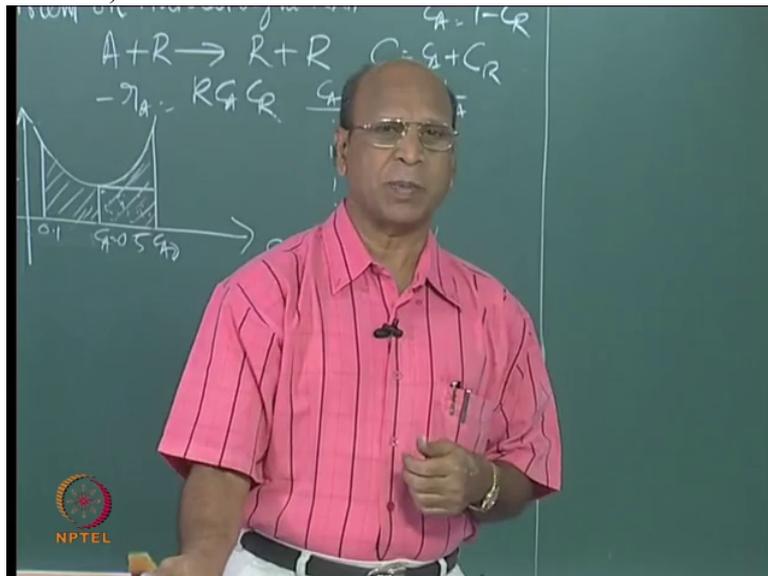
Abhishek, it is not asked 90 percent. The product should have 90 percent R. Point 9 R

Student: Yes, point 9 R.

Professor: Point 9 R, Ok so you can calculate from this equation what is exactly C A from that.
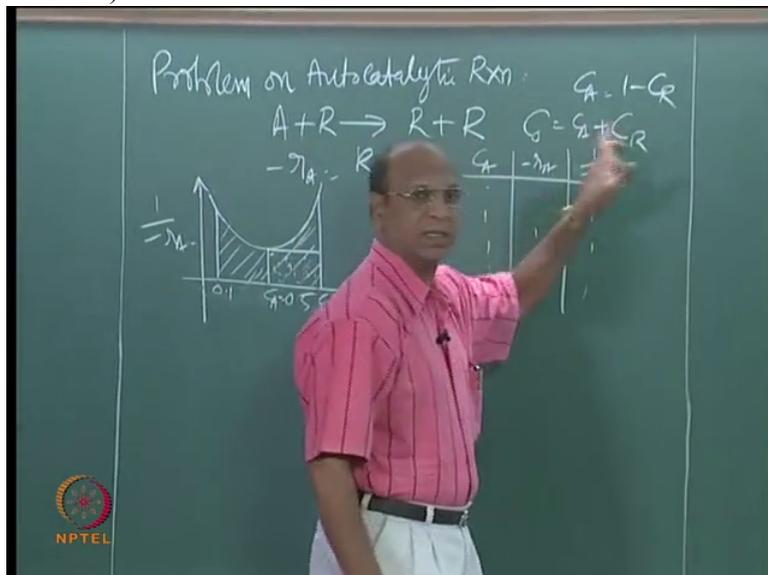
Ok. So then you will get you know that small difference will be there. That is why I was telling,

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it may not come exactly point 5, if I remember correctly, differentiate

Student: Point 5 will come.

Professor: Differentiate, if you differentiate and get it?

Student: Sir is that necessary that we should differentiate, because for autocatalytic reaction

Professor: See, if it is straight forward reaction like this, it is Ok. But to check yourself if that

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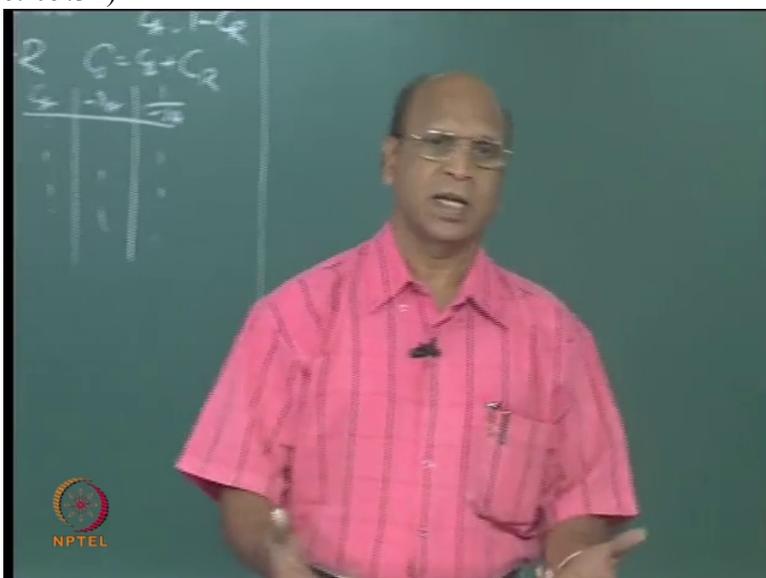
it is correctly coming at point 5 or what is that maximum, you have to differentiate.

(Professor – student conversation ends)

See, you are asking me as if you are always interested in writing the exam, right? So your idea is that when I am asking, I do not differentiate I will get Y, I will lose marks. Ok. So not

only...I am telling you no, all Indians are brothers and sisters, not much difference. They are keeping quiet. You are frankly asking.

(Professor – student conversation starts)
Student: In the figure

(Refer Slide Time: 05:57)

itself it is given the maxima rate is at C A equal to C R.

Professor: Which figure it is given?

Student: In Levenspiel it is given like that.

Professor: That is only for that, you know,

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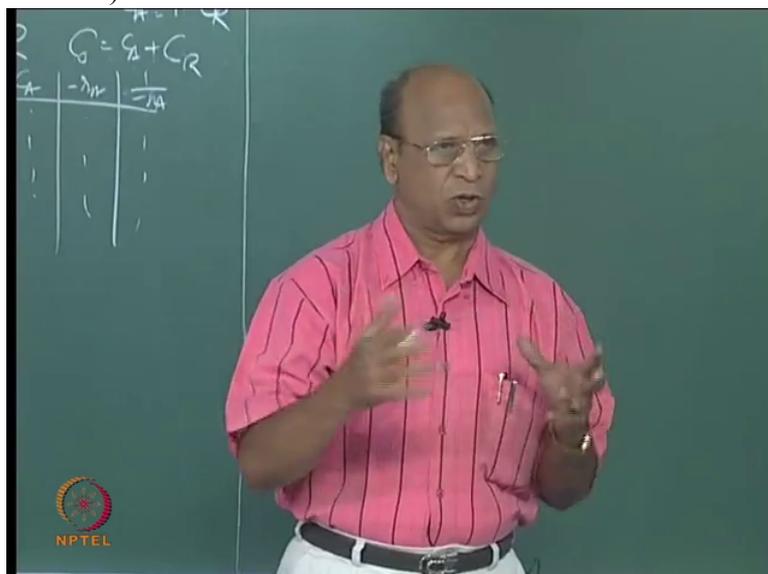
he has not given what are the initial concentrations, no?

Student: And 0:06:10.2 problem is given that

(Refer Slide Time: 06:11)

C A plus C R is equal to constant, which is 1.

Professor: Ok

Student: So naturally C A equal to C R is point 5

Professor: Every time you do not have to deduct like that.

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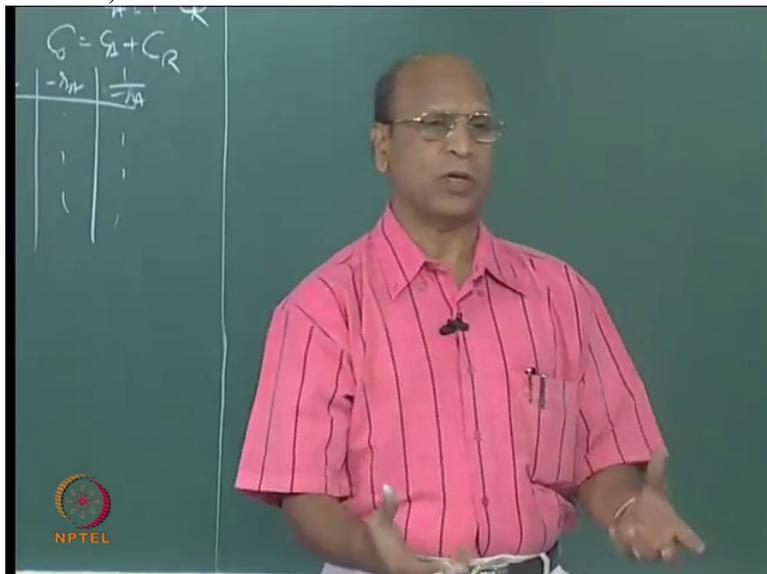
I mean why do not you do that once and, you know the differentiation and then find out what is the truth in that? Why are you getting point 5? And I can tell you with another; separate test saying that it is not it is not at point 5. I can also show that. Ok.

(Professor – student conversation ends)

So yeah, that is why I am trying to give you as much knowledge as possible and you are trying to convert that knowledge into marks. That is all. I mean that is also important for you but I think, knowledge if you have, marks automatically come. So that is the reason. Ok, anyway.

So like that you can, you can

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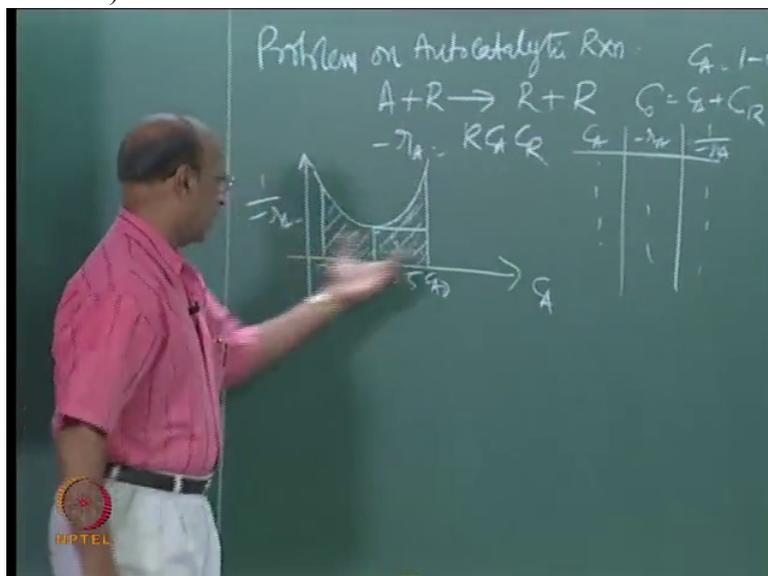
get all the possibilities. I will just give the final answer. You just try to find out whether what you get right or wrong, Ok. What is the first one, P F R right? Or you do not have that one, I think you would have torn it somewhere and then...

(Professor – student conversation starts)
Student: 6 point 8
Professor: Yes P F R, so what is the value you got? Tau equal to?
Student: 6 point 8
Professor: Yeah, 6 point 8 minutes. Or maybe

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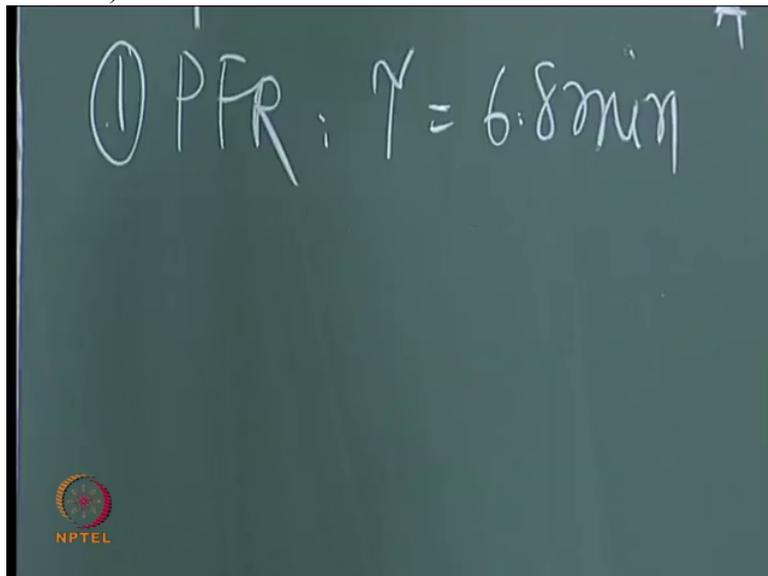
6 point 7 9, Ok, no problem. Ok that is fine. Yeah then what is the next one?

Student: 9 point 7 8

Professor: It is M F R

Student: 9 point 9 2

Professor: Yeah tau is equal to 9 point 9 yeah, 9 point 9

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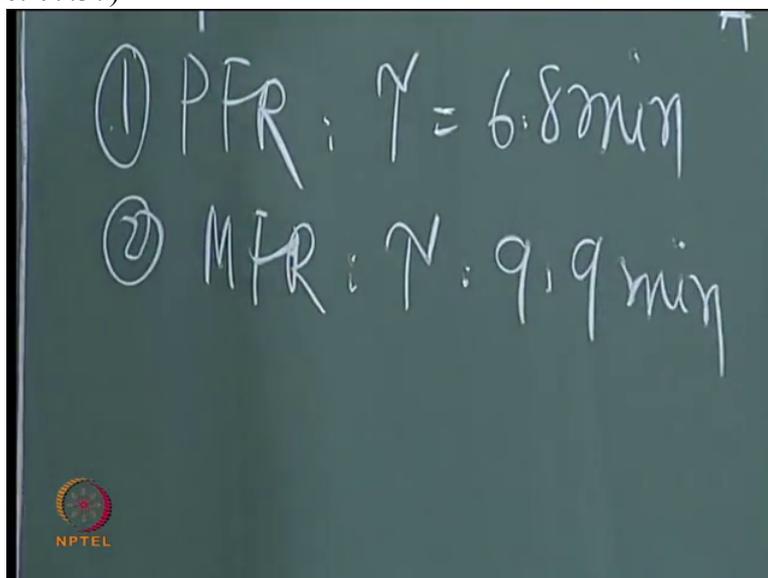
minutes.

Student: 0:07:40.4

Professor: Yeah, from here to the entire, from here, because it is plotted

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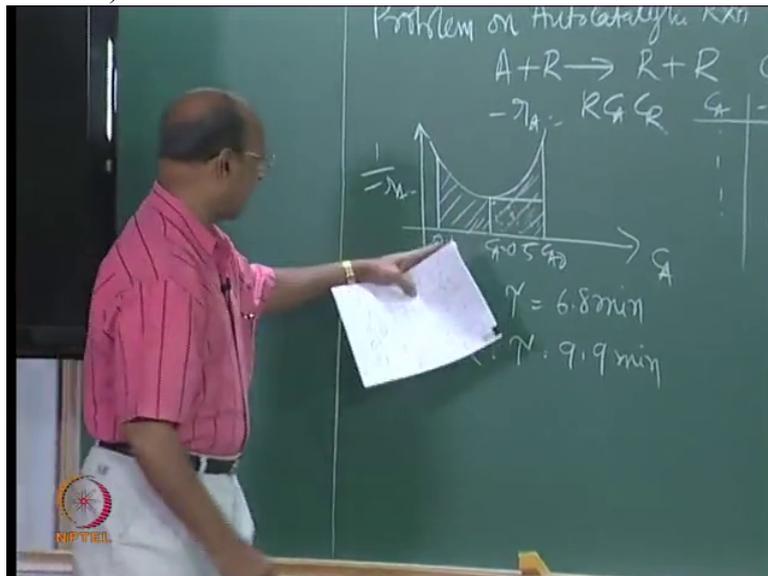
as C A by minus r A, 1 by minus r A. You can also plot X A versus minus r A also, 1 by minus

r A, Ok. So the next one, next one is two setup. Two that is M F R plus

Student: P F R

Professor: Yeah so M F R plus P F R, so this will be actually, tau equal to 2 plus

Student: 1 point 8

Professor: 2 point 2

Student: 4 point 2

Professor: Yeah 4 point 2 minutes.

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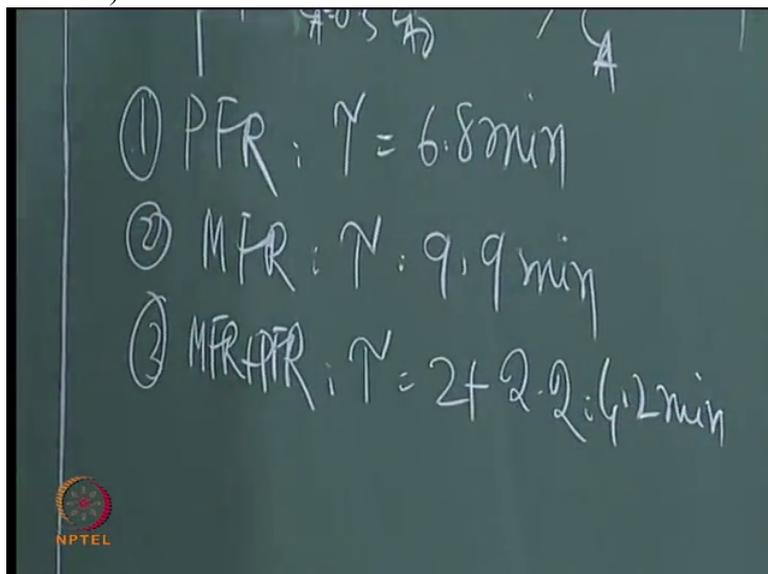
And of course, if it is only M F R, tau equal to 2 minutes.

(Professor – student conversation ends)

We should have

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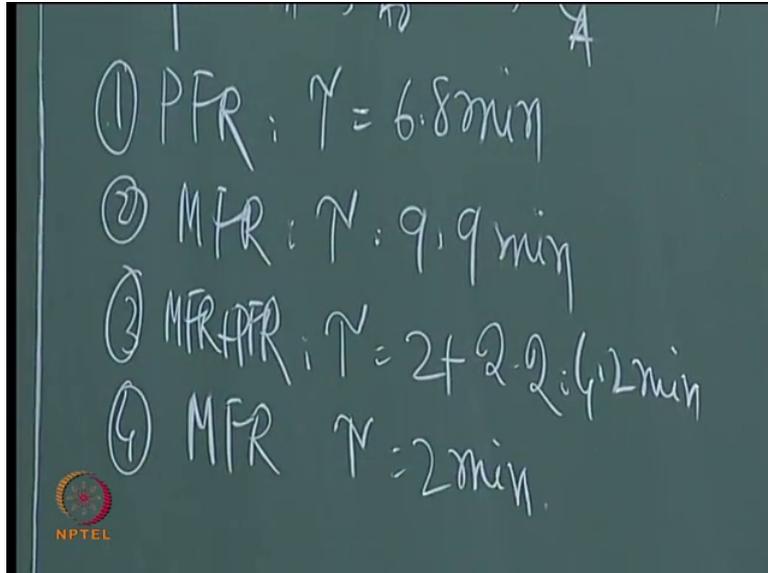
a distillation column or some other mass transfer equipment where you can separate it out, Ok. Even autocatalytic reactions and recycle is wonderful combination. The next one which I have not given you, which you are supposed to do, is find the optimal R for same conversion.

(Professor – student conversation starts)

Student: Point 4 3 6

Professor: You found out? R? R as 4

Student: First I took it to be recycle reactor and then I

Professor: You did it, Ok.

Student: Then I did

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Professor: Did you do it graphically or analytically? Analytically also it can be done.

Student: Everything analytically

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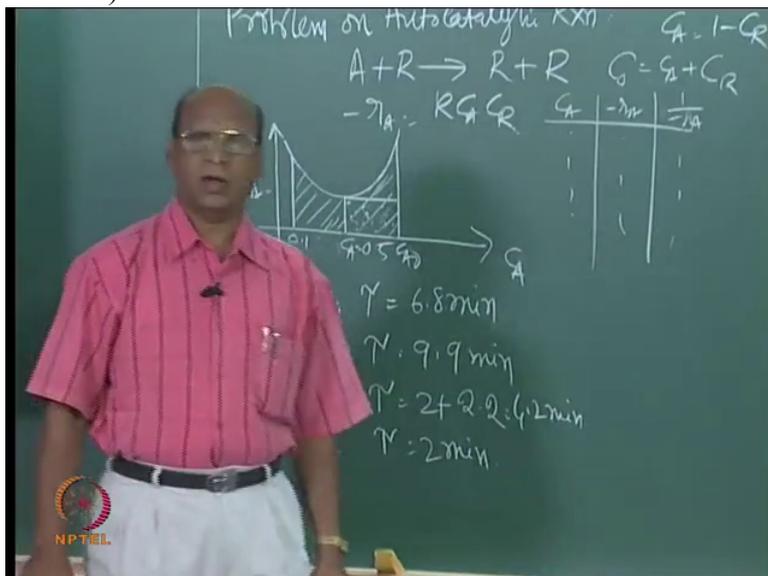
Professor: Oh everything analytical. Ok analytical also you can do this. You know all this you do not have to plot.

You can simply substitute, with this

V by F A naught I have been telling you many times this, this is R by R plus 1 X A f to X A f, yeah this is d X A by, this minus r A as k C A C R,

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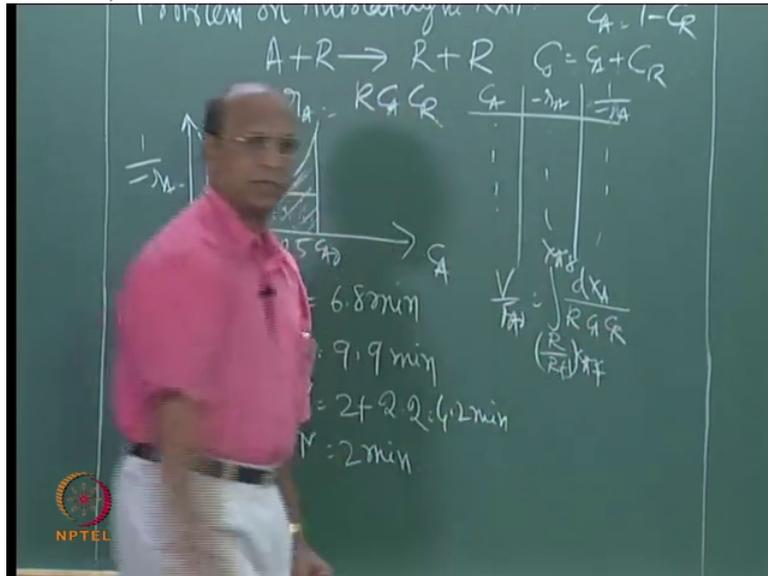
Ok. But only

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C A C R you have to convert into conversion, or you can also use, we have also this equation

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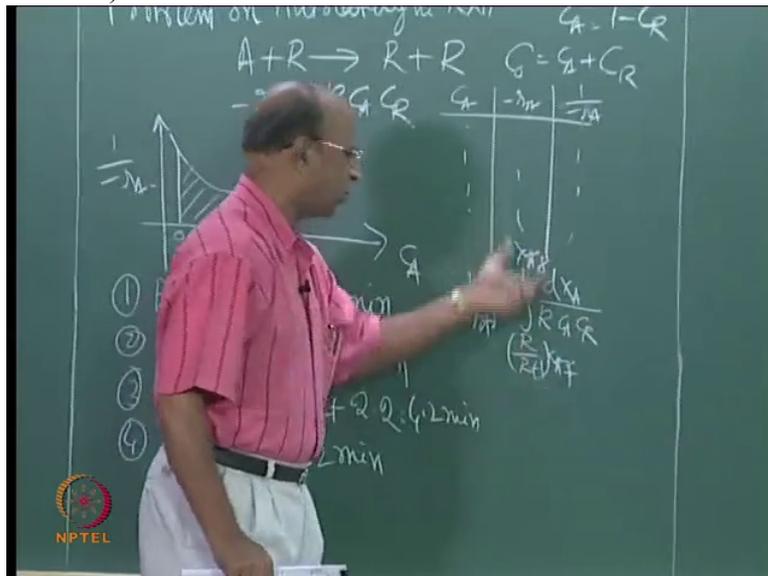
in terms of C A, the same equation, yeah minus r A

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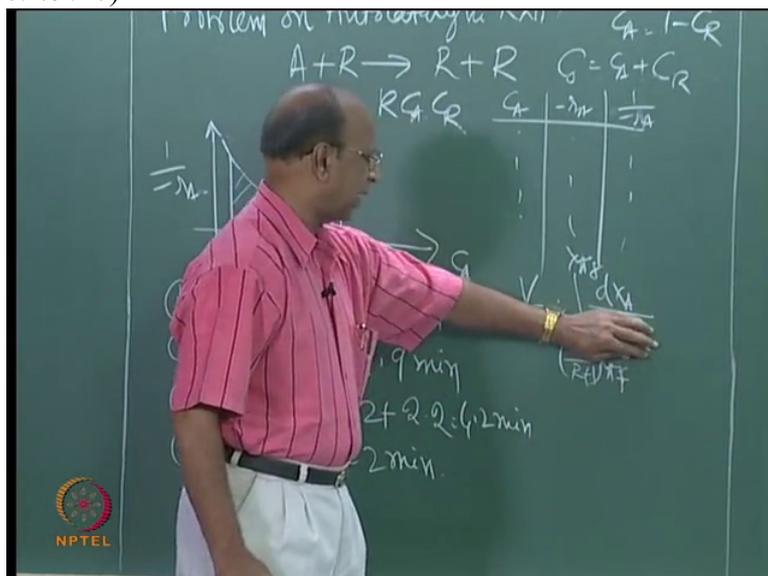
can also be written in terms of C A, right? This equation.

(Professor – student conversation ends)

So either you, whatever is, see once you are expert so then you can use your right hand or left hand. You know I think in at least in stories people say that that Arjuna, one of the brothers of this Pandava, he used to, I think throw the arrows it seems with right hand, left hand, with leg, head anything.

(Professor – student conversation starts)

Student: (laugh)

Professor: Because he is so much, so much expert, so whatever he, you know, way he wants he can put it. So that is what what you have to also do. Ok there is a proverb in Telugu also. Other langs also it must be there. If you have hair, you can put whatever hair style you want.

Student: (laugh)

Professor: Correct no? (laugh). Yeah. So but people like me, what they do? I think where is the hair style? Because there is no hair at all, first of all.

(Professor – student conversation ends)

So that is why when you have sufficient knowledge with you in your brain, then whatever way you can do it. But if you want to only prepare for examination then you want to only know one method. If that one method is slightly wrong there somewhere, then gone.

Because you do not have overall perspective. Ok. I mean many times I am telling but I think the moment you cross the door, you will forget everything. Ok. So this is what. Very good.

This is a nice problem and graphically if you want to do that recycle ratio to find out optimal recycle ratio, for recycle reactor, then you have to now try to draw these lines where this area equal to

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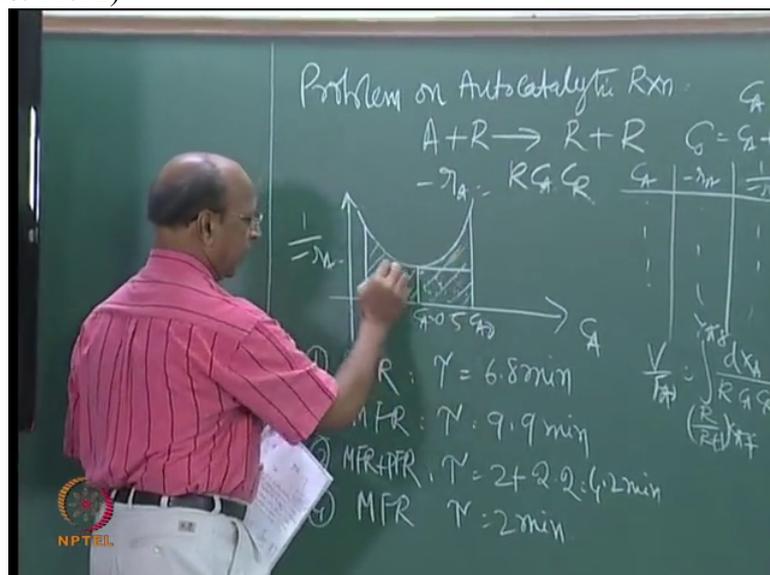
this area and somewhere here you will get R, Ok yeah, so X A 1, not R so that X A 1 equal to R by R plus 1 into X A f. That is one method.

Otherwise differentiate this; you know the condition, Ok. You write this in terms of,

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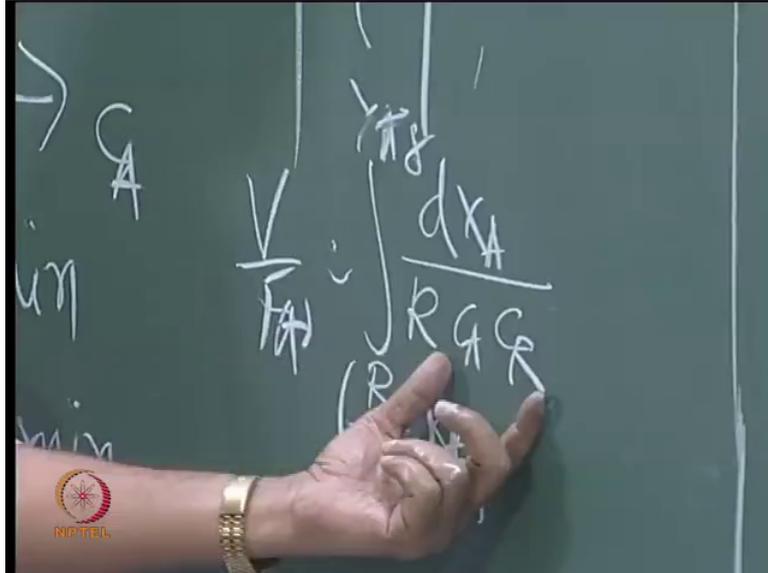
actually you integrate first and that integrated expression can be differentiated as

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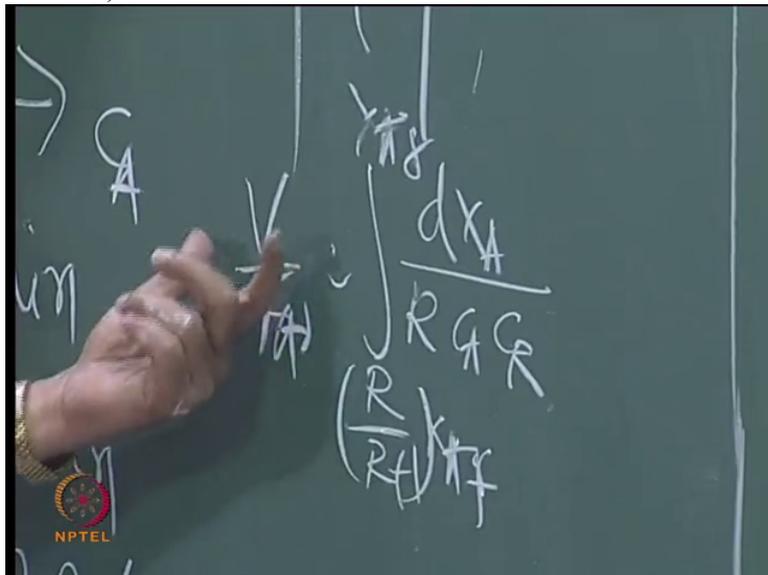
d of V by F A naught by d R equal to, d R, this is what again calculus, you know, what is the function with respect to what you have to differentiate.

This comes also in the next thing where you are talking of multiple reactions. In multiple reactions also you have to find out some times, optimal conversions or optimal volumes, Ok. Multiple reactions. Like you have done this already. I think I gave you this in the, first examination I gave you A going to R going to S?

(Professor – student conversation starts)

Student: No

Professor: I asked you to calculate 90 percent; I mean show that 60 percent something

Student: No, Sir, no

Professor: What was the first problem I gave? First problem is that

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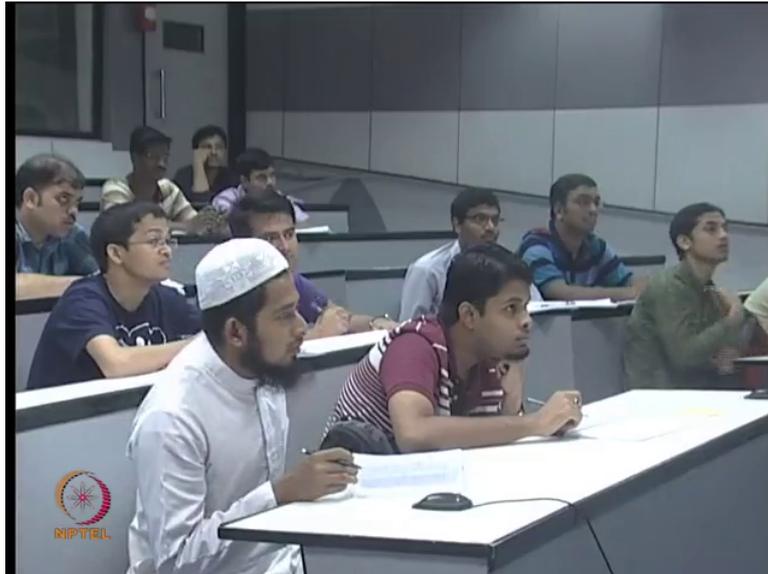
Student: derivation

Professor: Yeah, catalytic reaction, second one?

Student: Partial pressure, total pressure withstand

Professor: Ok, Ok, that is also another nice problem, A going to R, R going to S; find out

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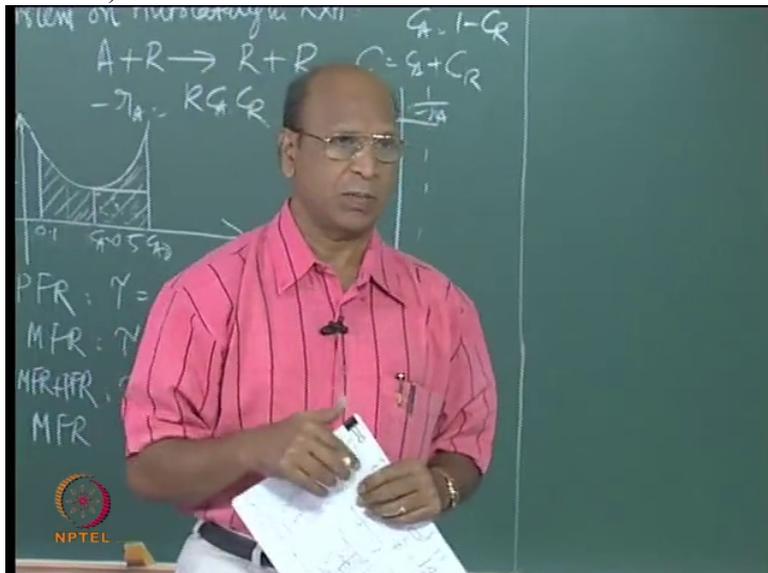
d C A by d R where you get the maximum, yeah?

(Professor – student conversation ends)

I think you also have no, when I have this kind of A going to R, A going to R, R going to S, then if I am plotting concentrations so C naught, C A naught is this, and C A will decrease like this,

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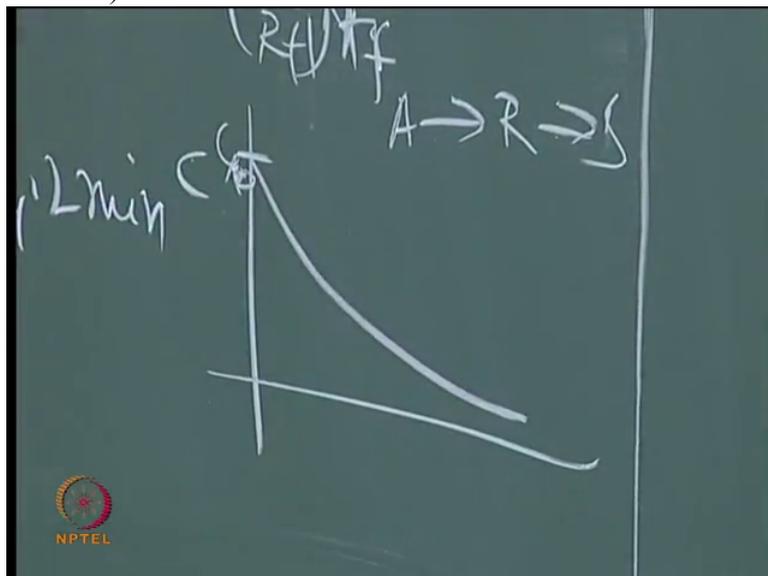
R will increase like this

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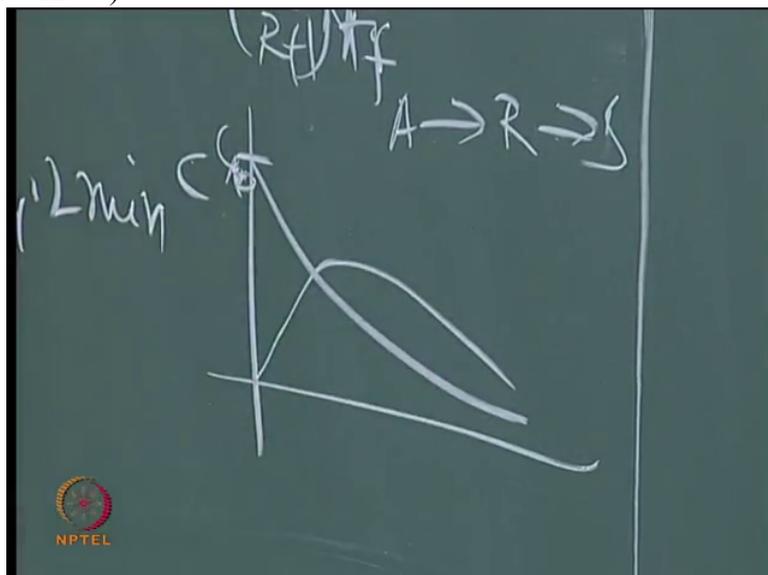
and S will
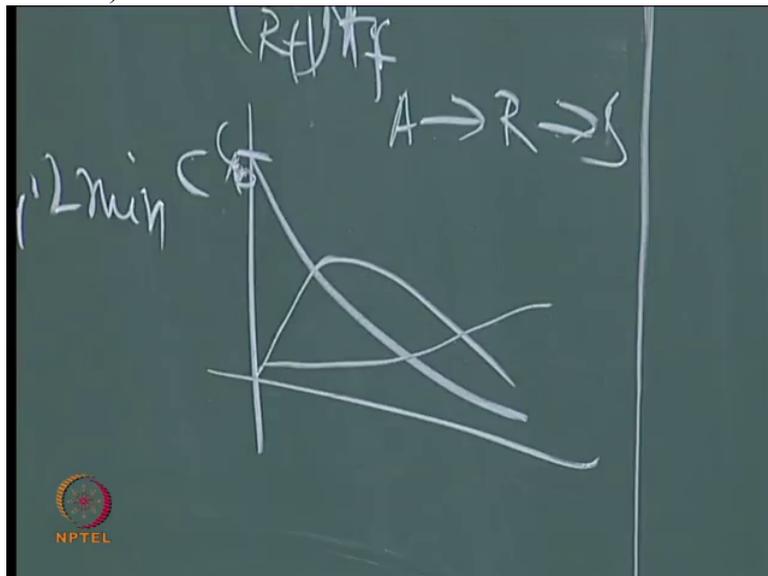
go like this, Ok. Yeah. So this is the one I am talking.

This also can be differentiated, you find
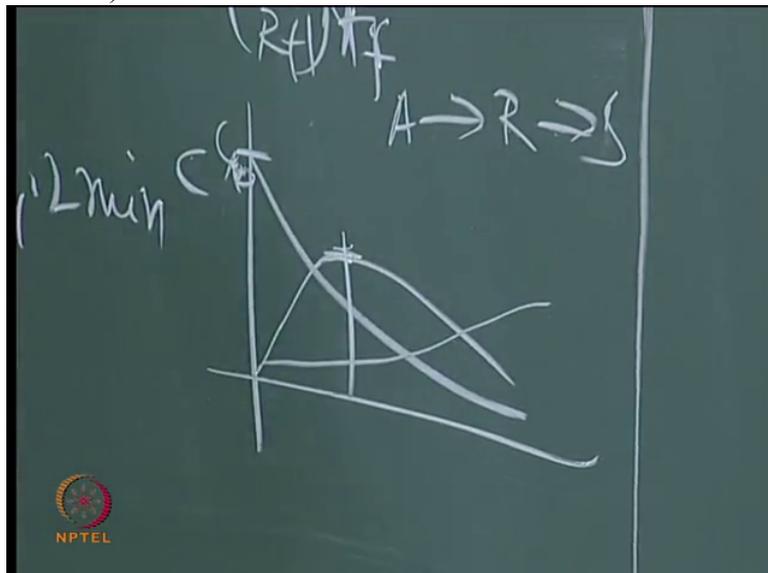
out C A. And then differentiate that with respect to time when I am plotting this versus time. Always graph should have x axis, y axis that is very important. Ok, so then you can also differentiate and find out. Good.

There are very nice simple problems where you test your knowledge how to differentiate and what kind of, you know problems particularly depending on k 1 values, k 2 values, this is k 1, this is k 2.

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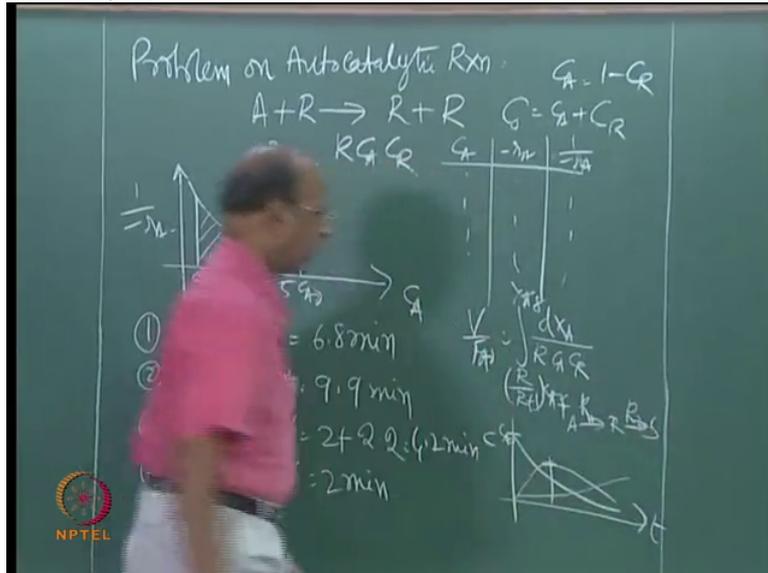
k 1 values, k 2 values. That is again you know if you have interest and if you are able to do all these problems with good mathematics background then I think you can easily score in this subject.

It is not that much complicated mathematical subject at this point of time. If you go to complicated things like you know the reactions are not simply constant density or reactions are multiply and with variable volumes, then you will have more algebra only, that is all. But conceptually you have learnt.

I tell you again I am guaranteeing that conceptually you have learnt whatever is basic things that are required. The additional things are delta x where you just add here and there, Ok, good. Ok.

So this is what. I think here, we will complete this part now with recycle reactor, that means ideal reactors we started and ideal reactors we thought only it is batch, plug flow and mixed flow. In continuous system it is mixed flow and plug flow. You know when you have to choose continuous when you have to choose batch. I think all of you, every one of you should know.

And then between the continuous two reactors mixed flow and plug flow, when do you choose plug and when do you choose mix? Swamy when do you choose?

(Professor – student conversation starts)

Student: Reaction is faster

Professor: Yeah

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wherever the reactions are

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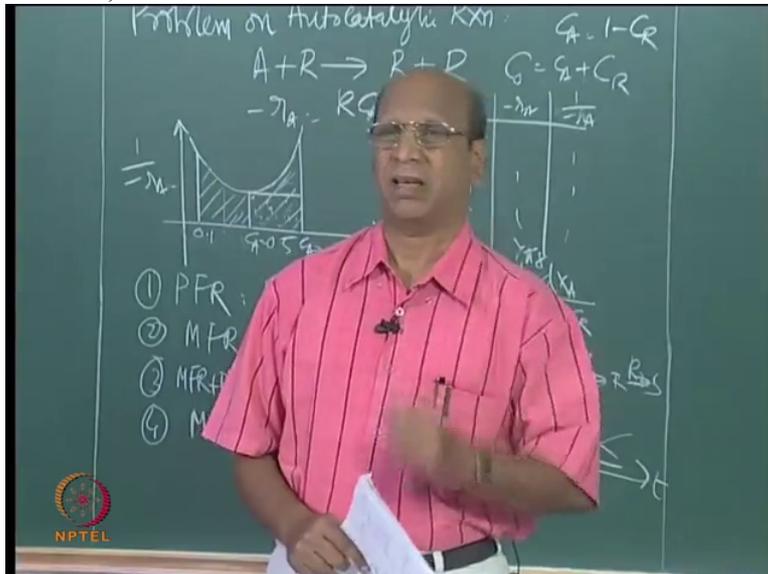
faster, Ok. Yeah and definitely where you do not choose plug flow is that when you want to have good

Student: Temperature control

Professor: Temperature control. You can never get good temperature control in plug flow reactor. Ok, even though it is efficient but as far as temperature control is concerned it is very, very difficult. Good. Ok those two.

(Professor – student conversation ends)

I think, mixed flow you know. Normally continuous is chosen for large capacities and within continuous again you have mixed flow. Whenever there is a temperature control which is very important, otherwise you know it may explode then under those conditions you always go for mixed flow, Ok, yeah. Or otherwise if you want to use still plug flow and then try to have a better temperature control?

Recycle reactor. It is not to increase conversion. This is the universal answer every student gives. To increase conversion put the recycle. No, you do not. Ok, you cannot. Because it is now, not the mixing is, the moment you are bringing back the recycle to the inlet stream, when you are mixing that, you are now trying to have control over mixing where there is no mixing in ideal plug flow. Absolutely there is no mixing.

And mixing is, it is not good for reaction. Very simple concept is whenever you mix two concentrations then you will have less concentration. When you have less concentration, rate of reaction will be less for; again there is a condition, n greater than zero, not 1 again.

This is another myth many people have. Ok, you can calculate for point 5 order and then show for mixed flow or plug flow which gives more conversion, right. So that condition is very important. If you have negative order reactions, dilute as much as possible.

If concentration equal to zero you will get infinite rate. Infinite rate means what is the volume?

(Professor – student conversation starts)

Student: Volume is variable

Professor: Zero. Zero volume because all these design expressions, that rate will be in the...

Student: Denominator

Professor: Denominator. Please remember that. That is why we want to increase the rate as much as possible, either through temperature
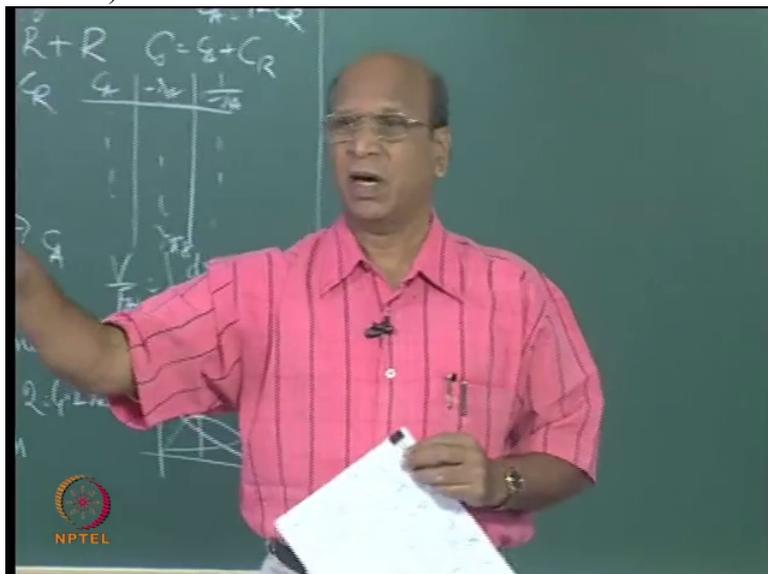
or through high concentrations, right or deliberately not mixing any streams. That is plug flow.

(Professor – student conversation ends)

Whereas mixed flow you are mixing two streams. The fresh reactant comes and falls into mixer where already it is converted may be 90 percent, 80 percent, 70 percent the way you are getting outlet concentration. Both are mixed. Mixing is instantaneous, right.

But the conversions you will get under steady state conditions because that much average residence time where it is defined volume by volumetric flow rate as, volume by volumetric flow rate as

(Refer Slide Time: 17:23)

(Professor – student conversation starts)

Student: Tau

Professor: Tau. That much average residence time is required for the reaction to go on. But why for that same average residence time, why you are getting less conversion in mixed flow, more conversion in plug flow? I am trying to explain it the other way. I told you also already? 0:17:45.3, telling something?
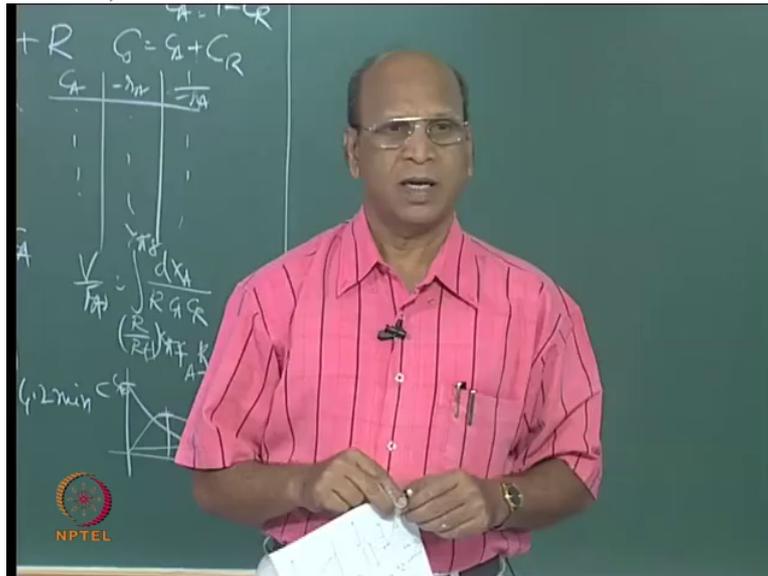
Student: Bypassing

Professor: Yeah, it is the bypass or indirectly residence time distribution is coming.

(Professor – student conversation ends)

Because the moment you have mixed flow, and mixing and coming out, so some molecules without spending much time at all, they are coming out. Conversion is almost zero in that, right?

So whereas,

of course it may take also long time, infinite time but there is no use of staying there infinite time because
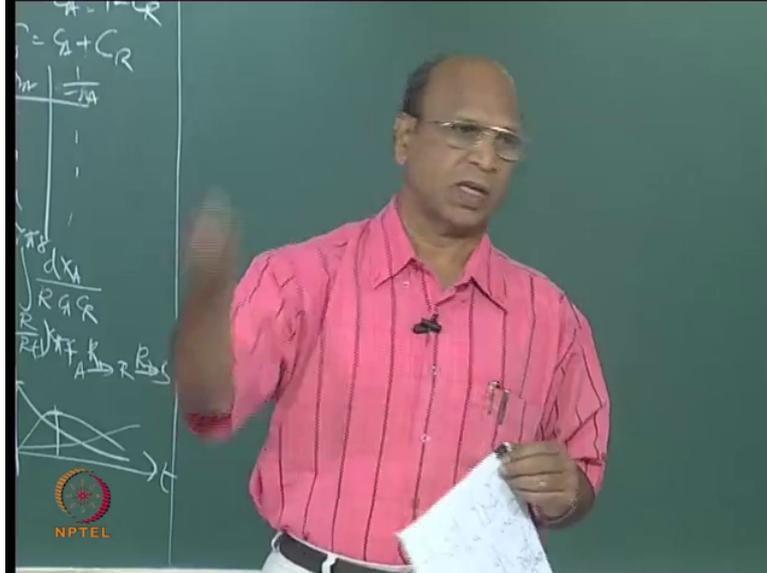
once it is already converted as product, then again that acts as dead space. Correct no? I mean what we expect is the good, you know the time for the reactants to react, not for the products to stay there. So that is the reason.

Again if someone asks you, Ok I have the same residence time in the both the reactors why mixed flow gives you more conv/conversion, less conversion

and plug flow gives you more conversion? The reason is residence time.

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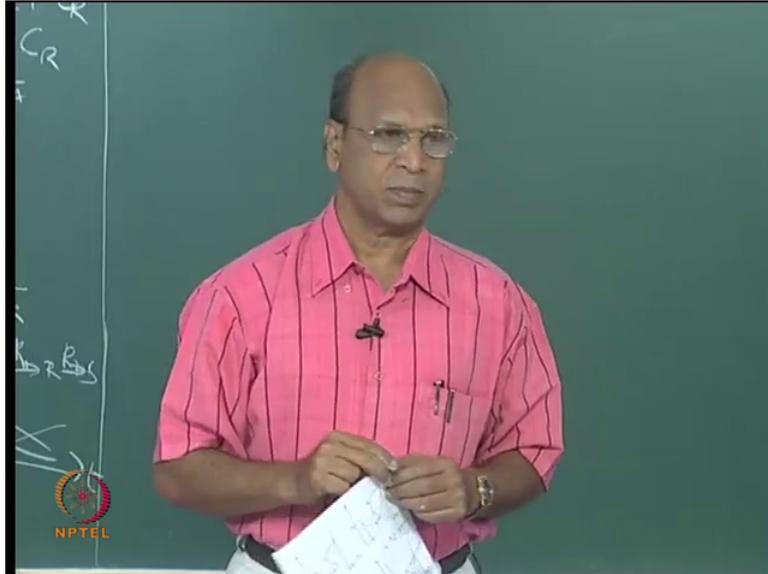
Residence time of individual molecules. Average residence time is same. Ok.

The average residence time is same but the individual molecules, individual packets if I look, some packets will come very quickly from the mixed flow where as all the packets exactly must spend exactly same time in the plug flow. That is why even if I break all

(Refer Slide Time: 19:02)

that packets and then mix them, then I will get exactly same conversion, there is no dilution there.

Whereas here I have dilution. I have a packet which is coming in one minute. I have a packet which is coming in 10 minutes. When I mix

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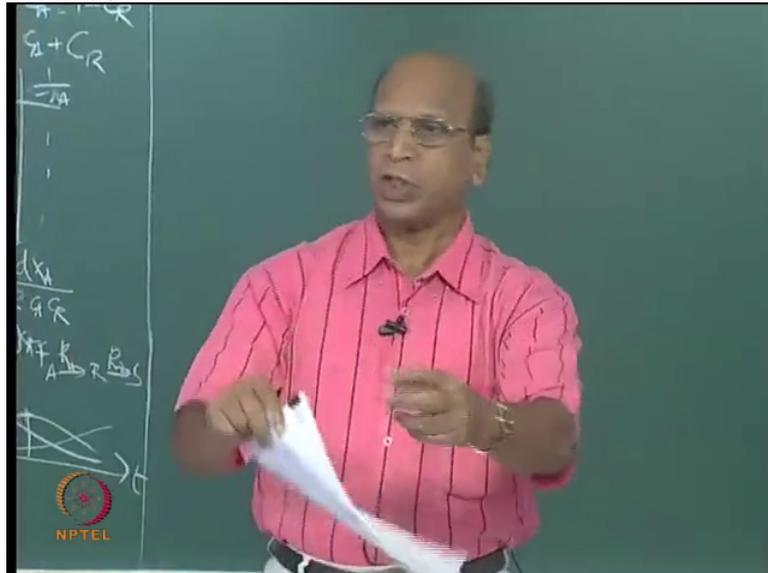
these two this is what I see at the outlet. The combination of all these packets that is what what you see in the outlet. Ok. So that is what is ideal reactor.

And you want to have recycle reactor, you will have only whenever you need some control over the mixing. And mixing can help you in controlling temperatures, reaction rate exactly; reaction rate or mixing also can help you in getting maximum products particularly for multiple reactions.

When you have some combination of reactants, A going to R, R going to S, again A is going somewhere, R is going somewhere, it is producing some other but only one of those products, either R or S is your actual product that is required, under those conditions also you can calculate.

I mean now we know, yeah this equation,

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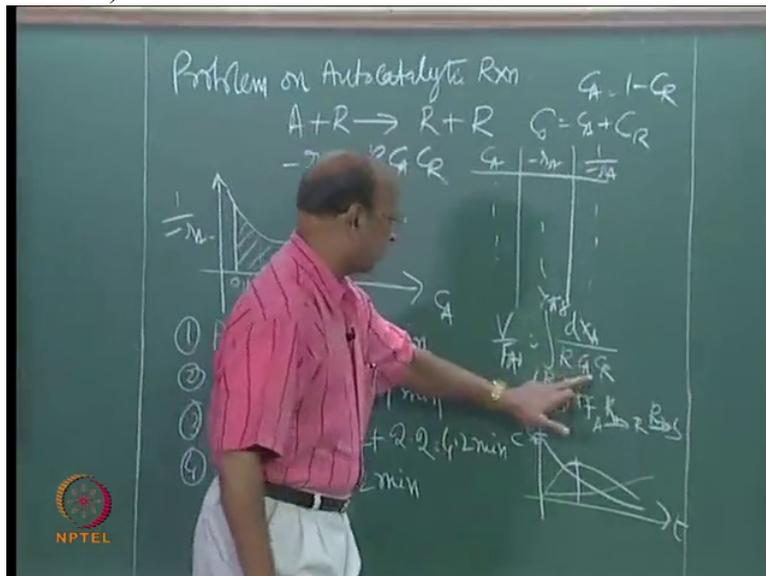
yeah that is all, this is the equation. And you can substitute that rate expression for A for a multiple reaction. Substitute here and then calculate conversion for a given volume. Ok from those conversions

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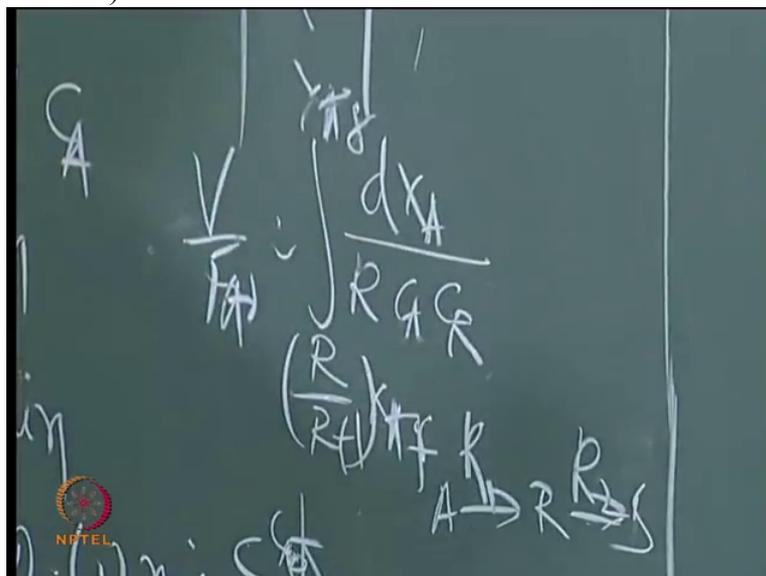
again you have the relationship between yield and conversion, that is what what we are going to do now.

So finally you will end up under some conditions, recycle reactor is the best. I will also tell you later which reactions are the best for that, Ok. But that is, there it is too much mathematical. It is not that easy to integrate. So that is why beyond certain point the chemical reaction engineering becomes very, very highly mathematical.

And as teacher if I start at that level of mathematics I think by this time you should have switched off all your brains. And I do not know; even now I am not guaranteeing that. Ok, some people would have switched off that already, I do not know. But with minimum mathematics you can learn beautifully all the concepts. Afterwards it is mathematics, mathematics, mathematics, whatever system you take.

It is only complications in mathematics and some techniques you have to use because you cannot integrate analytically most of the time, right so you have to go for some other technique or differentiation to find out maxima, minima and all that, Ok. Good.

So I think we will go, yeah so the ideal reactors, you know semi-batch reactors we are not doing but semi-batch reactors will also be helpful, particularly in finding out the product distribution. Like you know, if you have multiple reactions,

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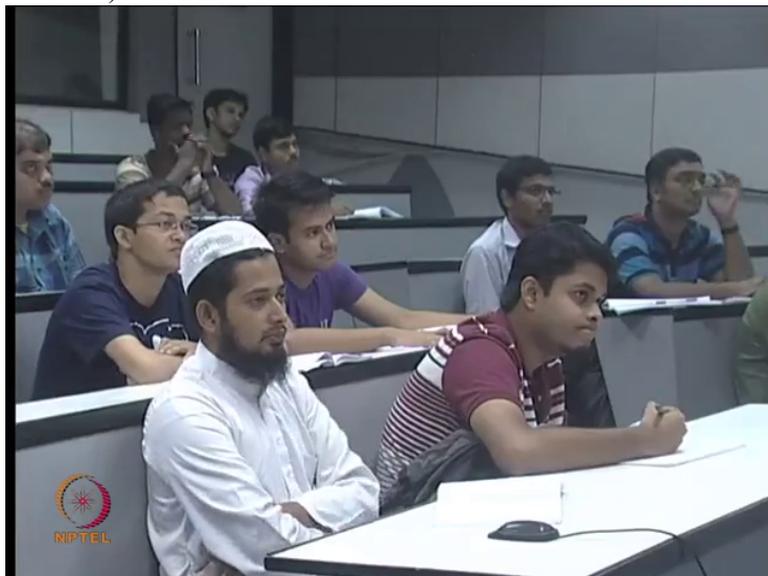
sometimes semi-batch reactions will give you more yield. How do you define yield?

(Professor – student conversation starts)

Student: 0:21:40.2

Professor: Yeah, yield means you know the concentration
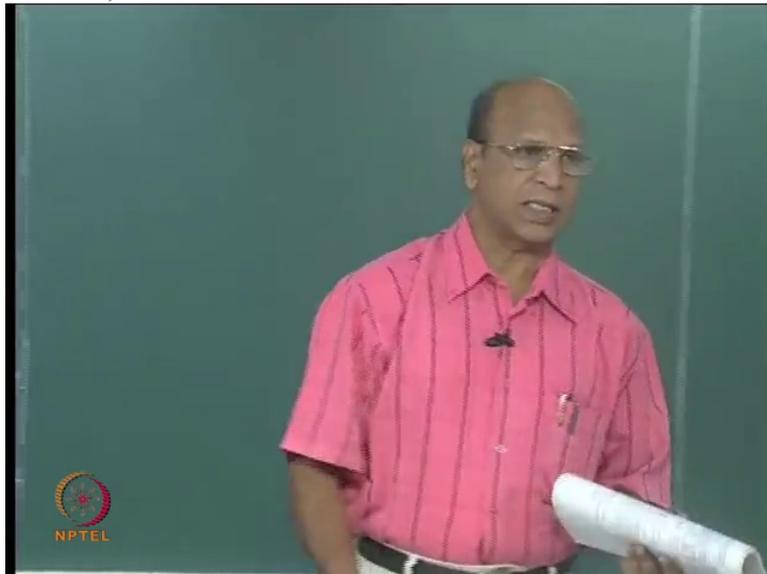
of desired product by, may be concentration product by...no, no, by undesired product if you take, that becomes selectivity. Yeah. So yield is at the input. Either C A naught or C A converted, that is what what we are going to do now.

(Professor – student conversation ends)

This is multiple reactions.

Our idea here is, if yield is clearly known to you, so much you have to get, you have to find out what is the volume of the reactor, Ok and yield and conversion also are related definitely, right?

So, or otherwise
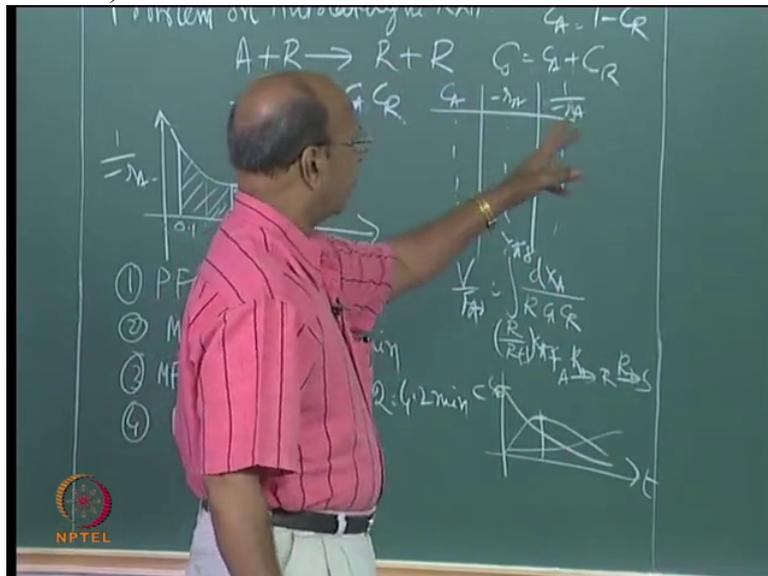
if I do not know what is the yield
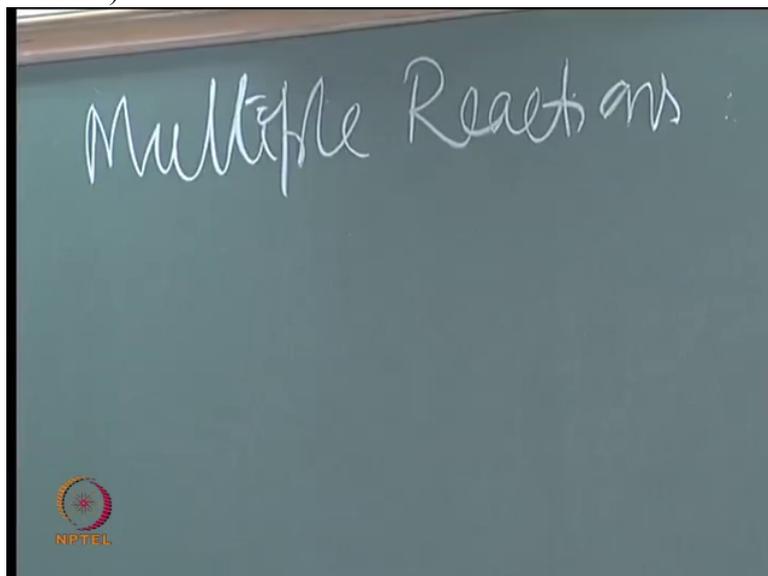
then I have to take a particular reactor volume and then try to find out in that given volume, what will be the maximum yield. Ok, so these are the same problems, given conversion finding out volume, given volume finding out conversion. But when you do you know conversion, or when do you know volume?

Again I told you know, I have to give the question and I have to answer myself.

(Professor – student conversation starts)

Student: When you have an existing reactor you find the conversion

Professor: I am talking about simple reactions; forget about, yeah product concentration

Student: C A, C A naught

Professor: These two problems I told you. One is known conversion, find out volume. Known volume, find out conversion. But when you do you come across

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these kind of two situations....

Student: Sir when you have an existing

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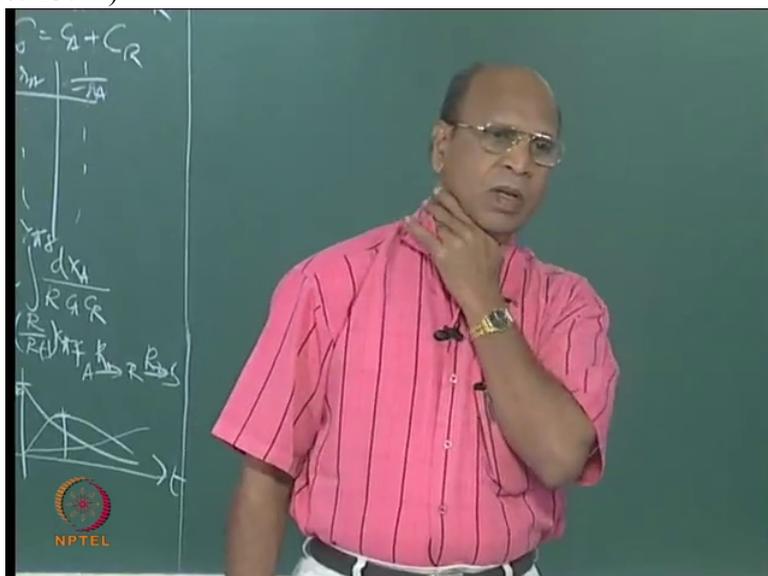
reactor...

Professor: Yeah

Student: Existing

Professor: When you already have existing reactor, maybe someone was

(Refer Slide Time: 23:20)

using earlier and he has thrown out and you want to use it.

Student: You can improve...

Professor: So taking that volume how do you maximize yield...

Student: Yield,

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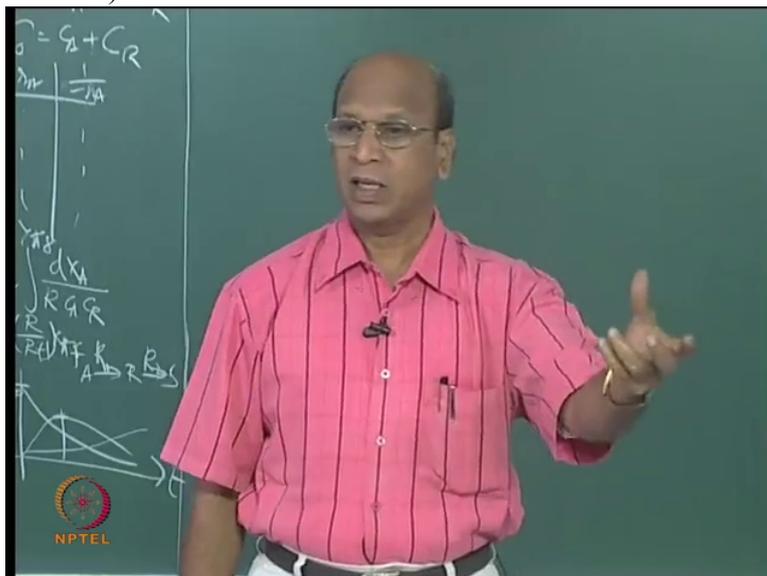
conversion

Professor: How do you operate so that you will get maximum conversion?

(Professor – student conversation ends)

Otherwise totally you do not have a reactor; you are designing a new plant where you do not have any equipment, totally new plant, Ok. So there everything starts with reactor. Even though reaction engineering taught in third year, fourth year like that, Ok but the actual process always it starts with reactor. That is what I think I also explained to you, no?

In fact we have taken more time and

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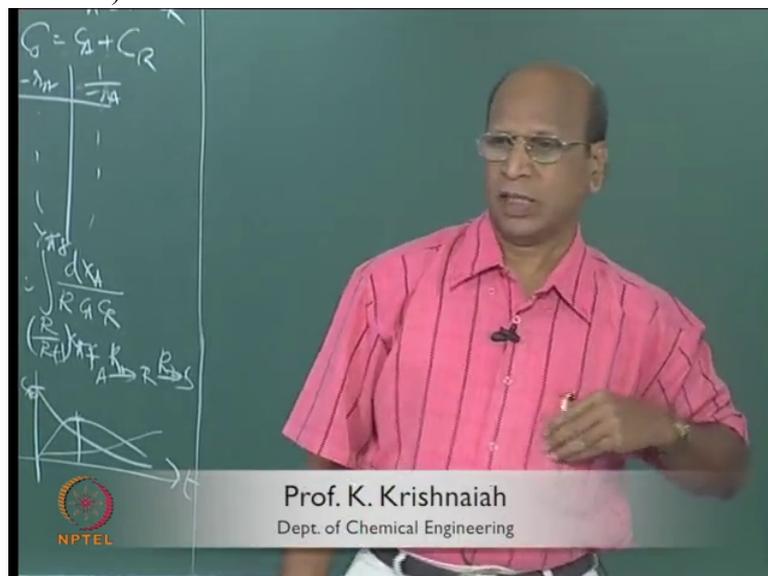
at leisure space I have explained to you how does a chemical process start. Some of you would have cursed me why this fellow is taking so much time for that. Ok but that only gives you what is the overall picture of what is going on in chemical engineering.

Otherwise if I come and start only reactors, you do not know where you have to put the reactors, Ok and you do not know how to connect with reactors and distillation columns, all that. So that is the reason why, at least at this point of time I have to tell that.

It should be done actually in introduction to Chemical Engineering in first semester, B Tech first semester, Ok but I think many people will not tell that, so whenever I have a choice, even if I go outside to give some talks, I will first start only with that. How does a chemical process start? And I am sure 90 percent of the people know, do not know. Ok. So that is why. The multiple reactions, Ok, please take this. I think I will give some notes. When a

single stoichiometric equation and single rate equation are chosen to represent the progress of a reaction comma, we have a single reaction. When more than one
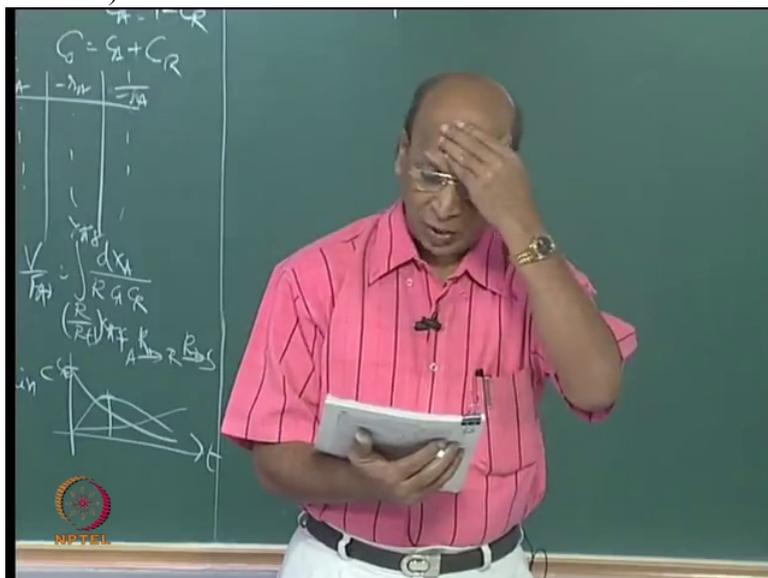
stoichiometric equation is chosen to represent the observed changes,

what changes we are talking about?

(Professor – student conversation starts)

Student: Reactant changes

Professor: Yeah, concentrations, concentration changes, Ok, observed changes comma otherwise if you are not able to follow, write in the bracket, concentration changes, then more than one kinetic expression is needed to follow to change in composition of all the reaction components comma and we have multiple reactions.

(Professor – student conversation ends)

Actually these are
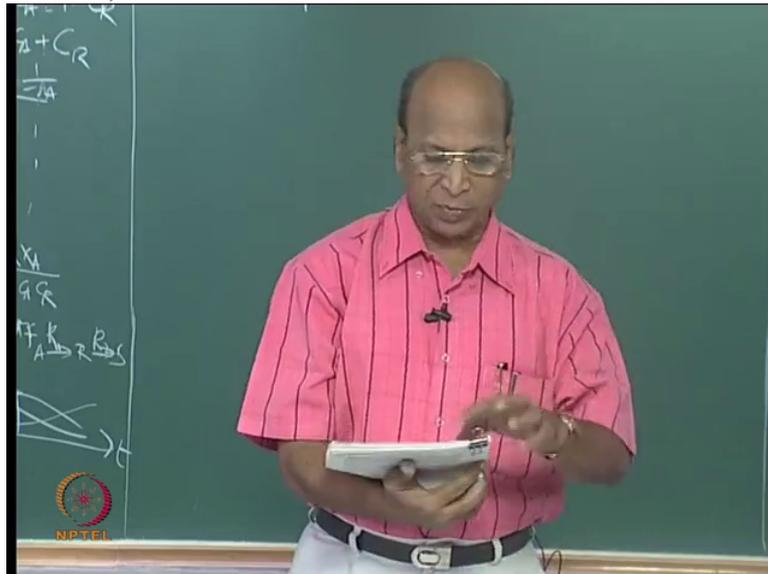
the definitions which I asked you in the first zeroth examination. Differentiate between multiple reaction and single reaction, Ok. Single reaction definition is not simply A going to R, right? Important thing there is you need only one equation and one stoichiometry to represent the changes.

It may need not be only A going to R. I may have A plus B plus C going to R plus S plus T plus, till X Y Z. How do I represent all these compositions, with time if it is a batch reactor? I need only stoichiometric equation. Because now A plus B going, or A plus B plus C going to R plus S plus T plus U plus, you know V plus, all that is there. But if I know one mole

of A, I know how many moles of again that side R is forming and all that. So one equation is just enough.

Whereas if I go here, A going to R, R going to S,

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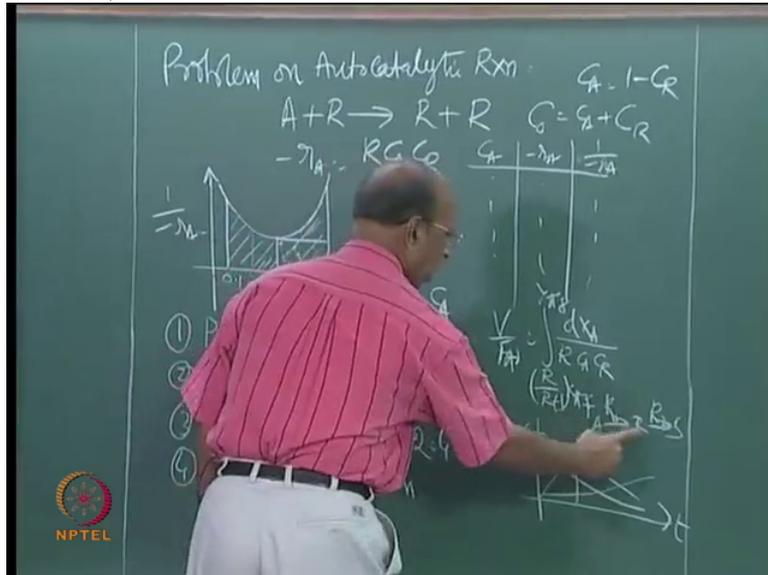
I cannot use only one stoichiometric equation because this also can be written as A going to R also R going to S.

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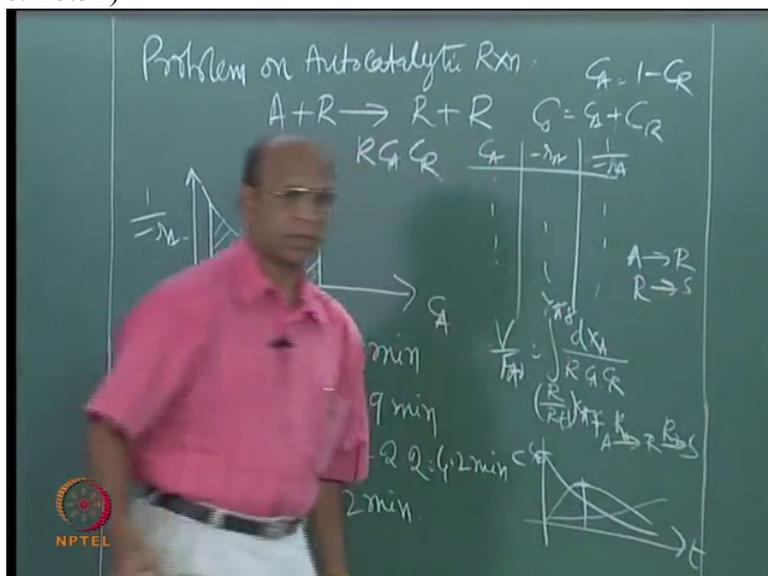
So I want, if I want to find out the composition of A, R and S, I need

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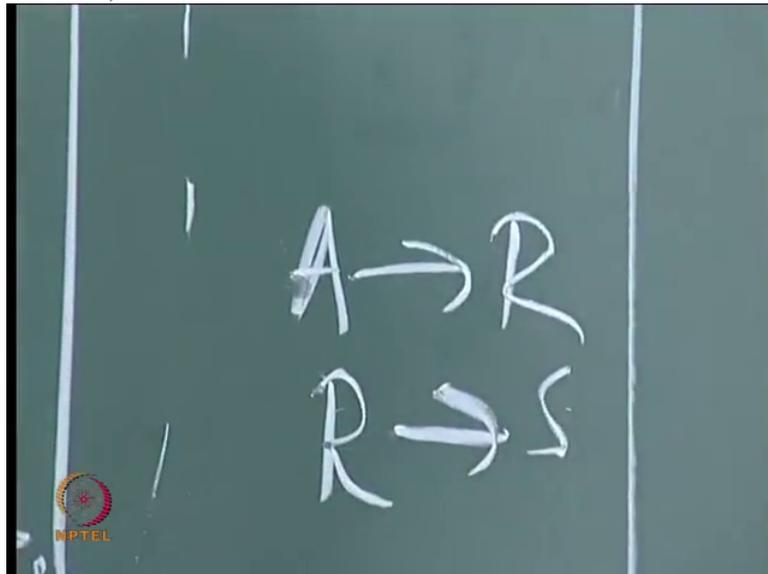
again minimum 2.

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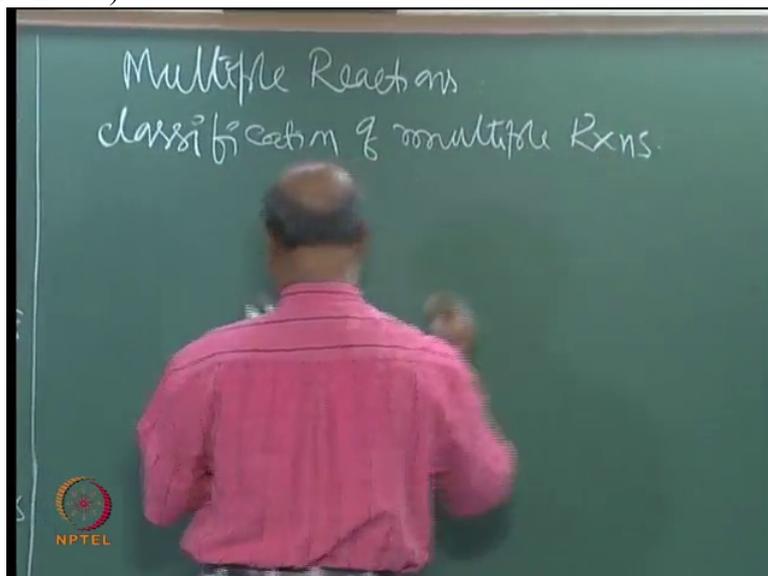
Third one also you can do it, but I think not required, by material balance you can find out the composition of the other one. Because the total mass anyway that is same, right? So that is the difference actually between multiple reaction and single reaction.

Single reaction when you say you have a single reaction that means you have only one stoichiometric equation and one rate equation. Whereas multiple reaction means you have more, yeah you need more than 1 rate equation and of course stoichiometric equations also will be more. That is the definition.

In fact, that is what also I told in that para. Even though without thinking you would have just copied whatever I said, good, Ok. So then the reactions can be classified as, classification, it is not that easy to easily classify but some simple things we write here.

Classification of multiple reactions, Yeah. So we have series reactions, A going to R, R going to S

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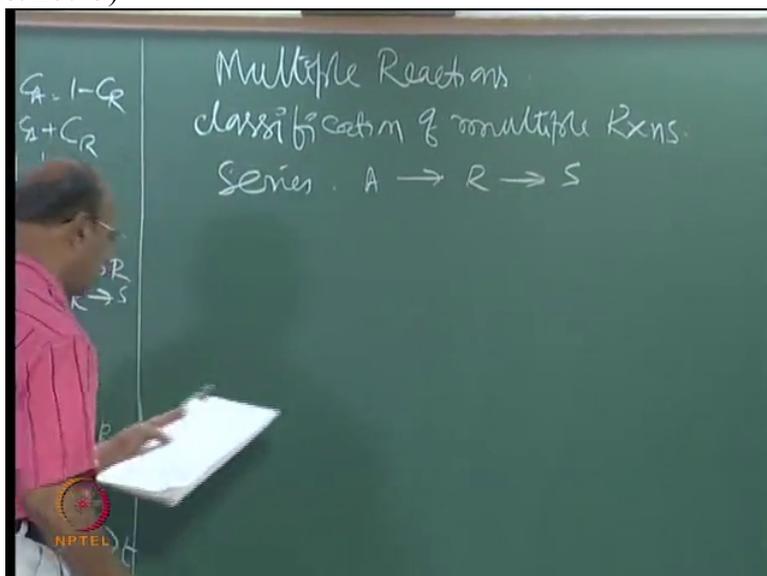
parallel reactions are A going to R, A going to S.

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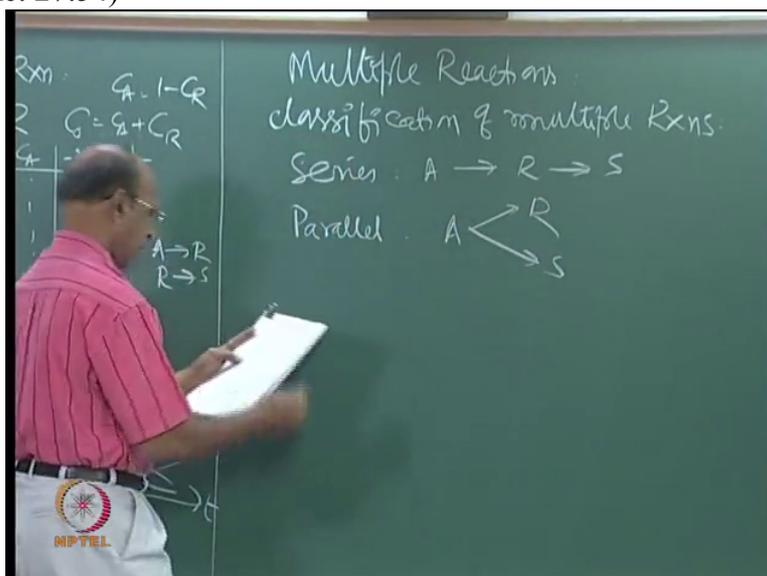
And we can also have for example, A going to R side by side reactions, B going to S, both are there. A and B both are there,

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so A may go to one and B may go to another product.

So I mean any combination. I have written here very simple thing, A going to R,

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R going to S, so that algebra will be simple. Ok. But this also can be A plus B going to R. And R again may give S plus T. Ok; this is where you will have L in reaction engineering.

That is why you should be good in simple calculus. Because I think it won't go, you won't go beyond this d CA by d t, or you won't go beyond you know, either differentiation or integration of first order only. It is not more than that. But I think unless you have that practice, that mathematics practice only I am telling.

So I have given here single, I mean simple but it can be very complicated but our requirement is this is a step
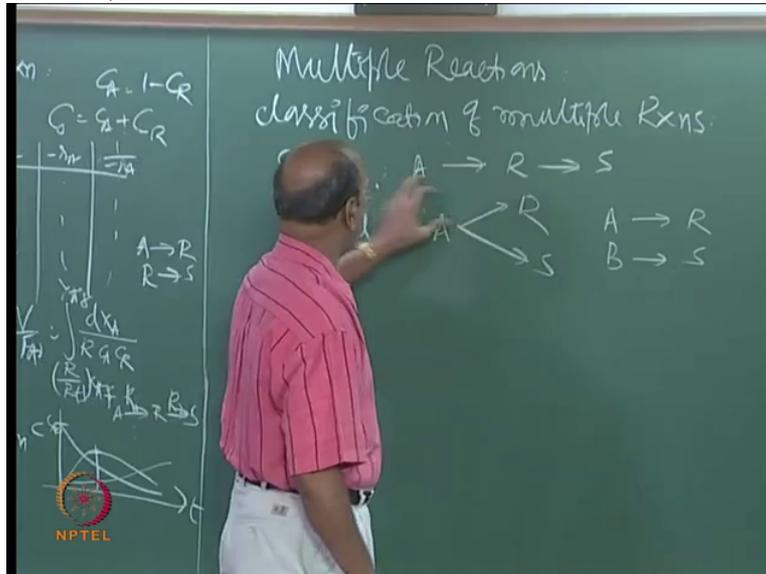
and the intermediate component is giving me another reaction. Then you have the series. Ok, one after the other.

Whereas here, need not be one after the other.
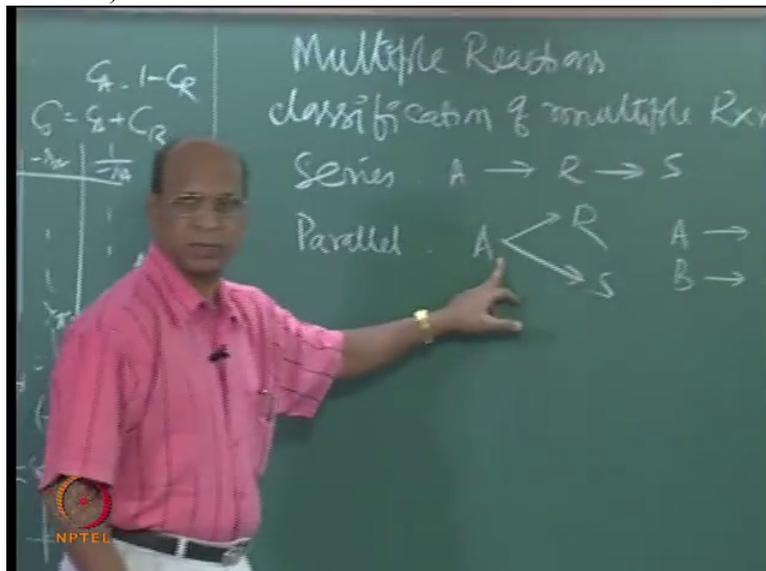
A is separately giving R and also A, some part of it is also giving S. It is not first R and then S. Ok. There are many combinations. In fact, in industry, there are many, many combinations like that. In fact this also go,

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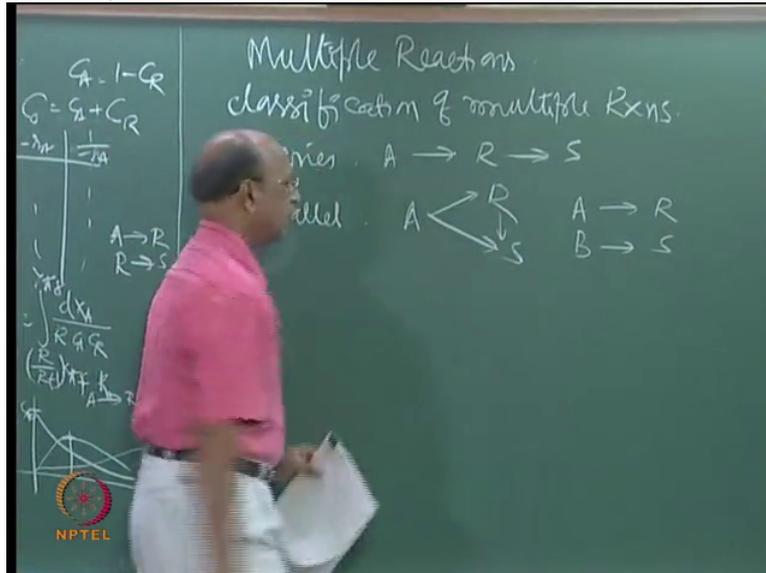
R going to S again. A is going anyway to R. And A also is going to S. And again R may give me S.

You see I think, is really very, very complicated. Now your objective may be to get maximum R. Maximum S is fine,

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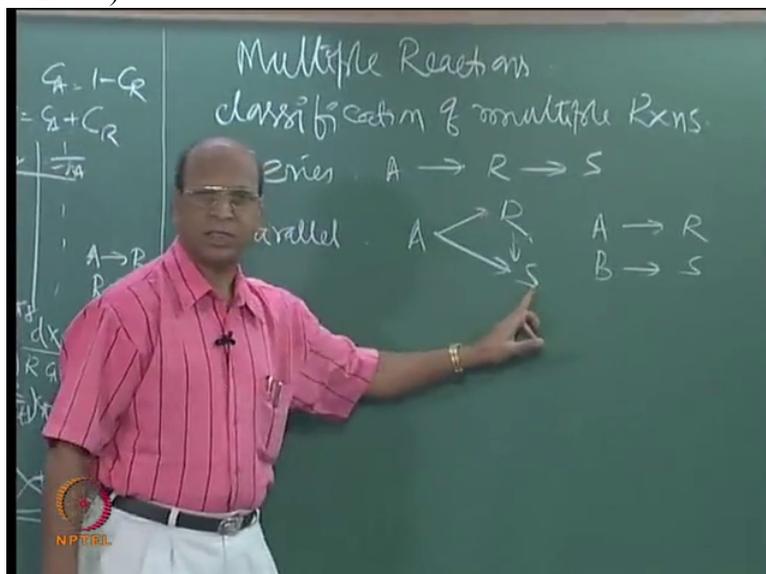
it is not that difficult. Why? Anyway this fellow is going here and from there again he is coming here, so what we want is maximum here. If you want to have this R maximum, then you have to try to control, either through temperature so that means you have minimize this rate as much as possible, theoretically zero. But it is not possible to go for zero.

So that is why you have to see that what is the, what are the parameters what you have. You have temperature and you have concentration and also you have a reactor. So that means how do I minimize my R as much as possible in a particular reactor. When do you get low concentrations of some reactants in the reactors?

By definition C S T R gives you always low concentrations, you know, maintain low concentrations, right. P F R maintains high concentrations. This is also another reason why you have P F R giving you more conversions and M F R giving you less conversions. You see in how many ways you can define, I say.

That is what I told you, if you have sufficient hair, Ok, then always you can try to put whatever hairstyle you want. So that is why that thinking, that brain, thinking, that is very important for us. Good. So this is the one.

Then now we also have series, parallel, this combination, series parallel combination, all of you must be knowing all this but still A going to R but now, so like that any number also

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we can write. So with respect to what it is series and with respect to what it is parallel?

(Professor – student conversation starts)

Student: With A it is parallel

Student: B it is parallel.

Student: A R

Professor: Yeah and A going to R, R again going to

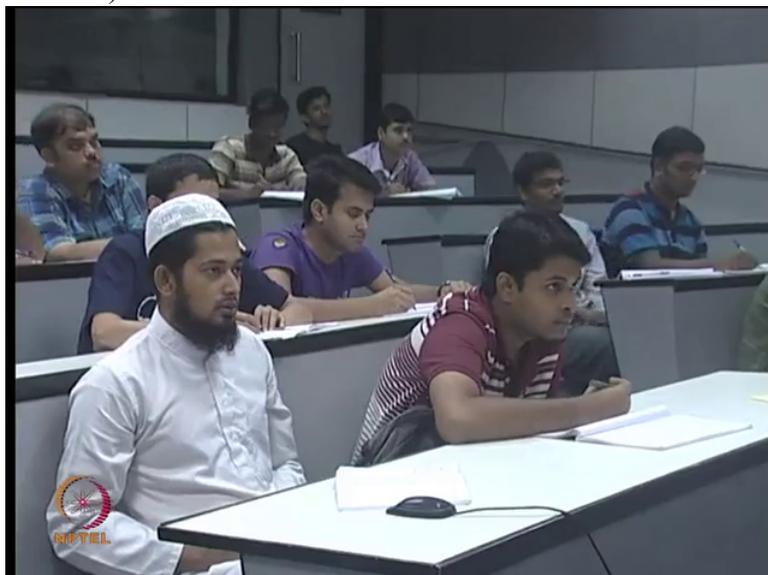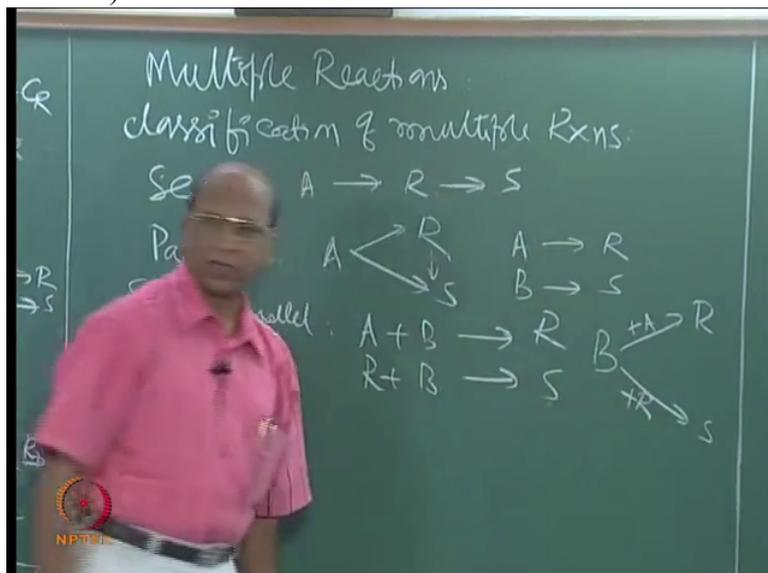(Refer Slide Time: 31:28)
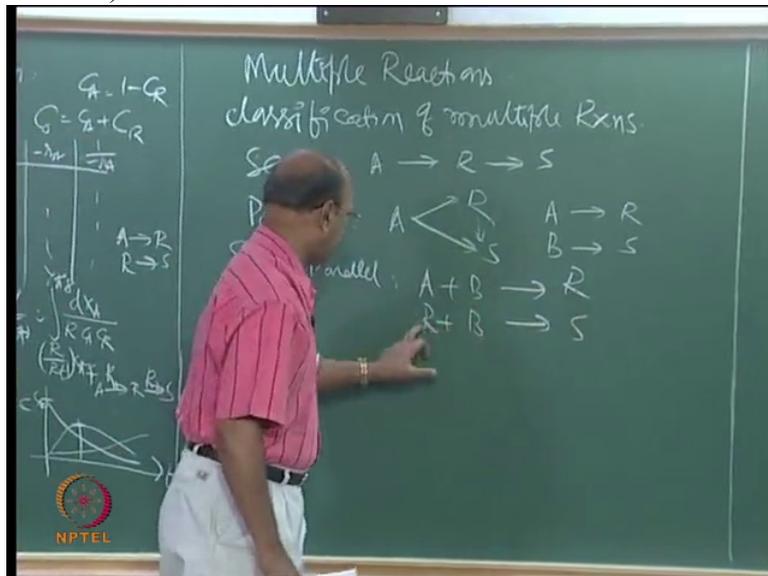
S. Ok, you can also write this in terms of individual components.

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Like, if I have B, this is R then this is S, how do I represent? Here I should have plus A and here you should have

plus R, that is parallel. Series also we can write. How do I write series?

Student: A going to R

Professor: Yeah, plus B

Student: R going to B

Professor: Yeah R arrow plus B gives you S. So that is the series representation, so that is how what we can easily imagine that.

(Professor – student conversation ends)

And there are many complicated reactions also I will tell you, some more reactions, Ok, I think let me tell here itself. Ok, so I also may have another reaction called, simple thing we start first. This is small v, actually it is called van de Vusse reaction, it is name of a person.

And we call as, you know van de Vusse, right because we know v, but in many European countries they call V as Fau, F, Fan de Fusse, Ok, yeah. Fan de, Fan de. I think there is a movie actor also, no? Fan Damme or something?

(Professor – student conversation starts)

Student: van Damme, yes Sir.

Professor: Fan Damme, action, action

Student: van Damme

Student: van Damme

Professor: van?

Student: van Damme.

Professor: Slightly old actor. Now

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I think, you know. Yeah, I think all action, very clean movies, only action, nothing, nothing else. Good one. I think fan Damme. Yeah, that is what. It is not van.
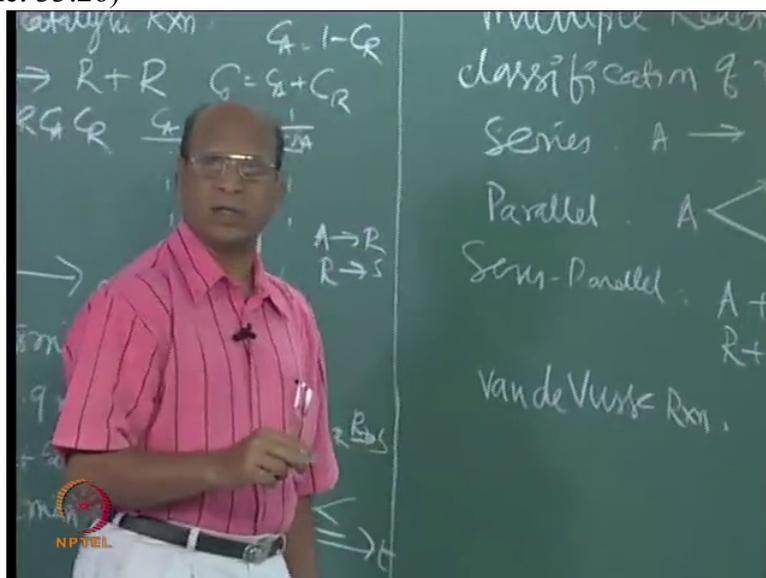
Student: van Damme

Professor: It is not car or it is not van.

Student: (laugh)

Professor: It is fan. v a n they call as fan, Ok, fan Damme,

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D a m m e, I think, Ok, yeah. Now I think you have to go to Google and see whether what is the correct name and what are the movies he has done and all that, Ok.

(Professor – student conversation ends)

So this van de Vusse reaction is A going to R, R going to S and here again, going to some product T. And here normally we will represent, these are the, yeah

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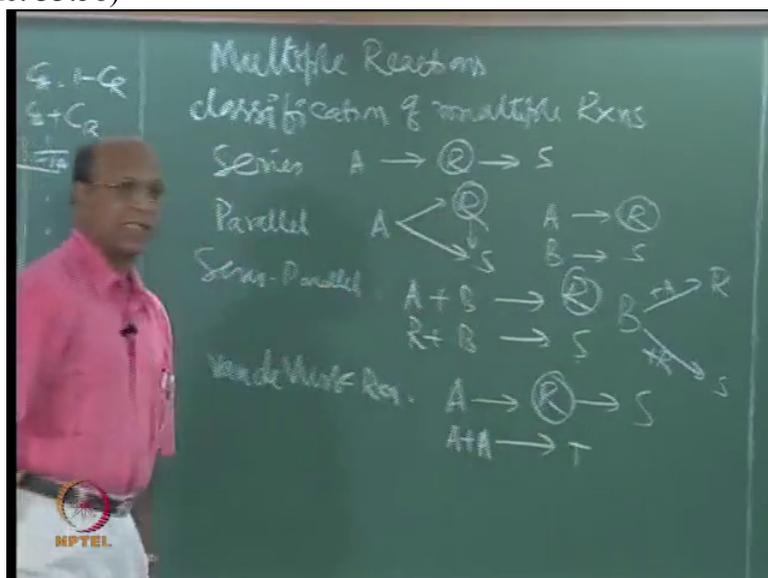
these are the desired products. That means I am interested in finding out yield of these.

What is the problem here? And all these things you know when you are discussing, we assume that we have elementary reactions, because if you complicated things, complicated things will come anyway through mathematics.

But to understand the basics, the first, you know the concepts, we will go to the simple ones like this, all these reactions are elementary reactions and also they are constant density systems. So that mathematics wise I can simplify.

Because beyond certain point, you know in certain courses you would have felt that also. After some time if there are too many mathematics, you lose. Hands up. Ok that means mind cannot, cannot you know perceive all that and remember. Like for example I can tell you very simple demonstration. Ok. this is the limitation of mind.

So how many chalk pieces are there? 1, now, now...

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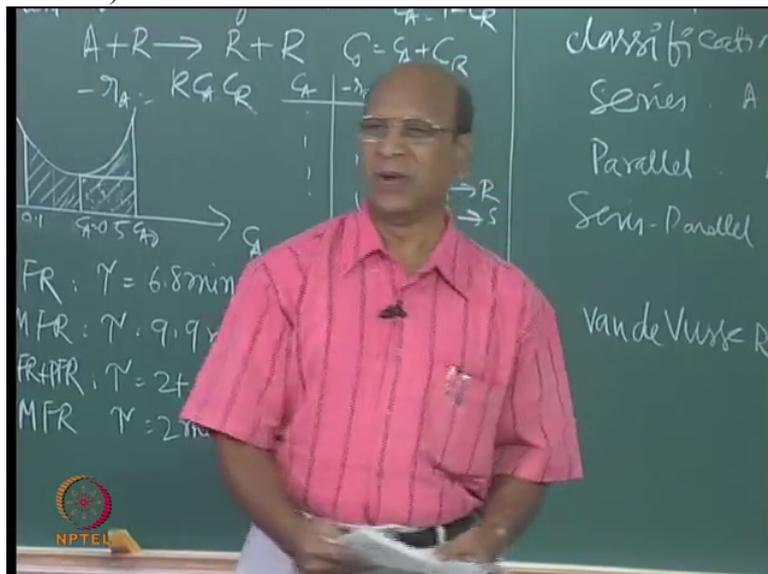(Professor – student conversation starts)

Student: 18

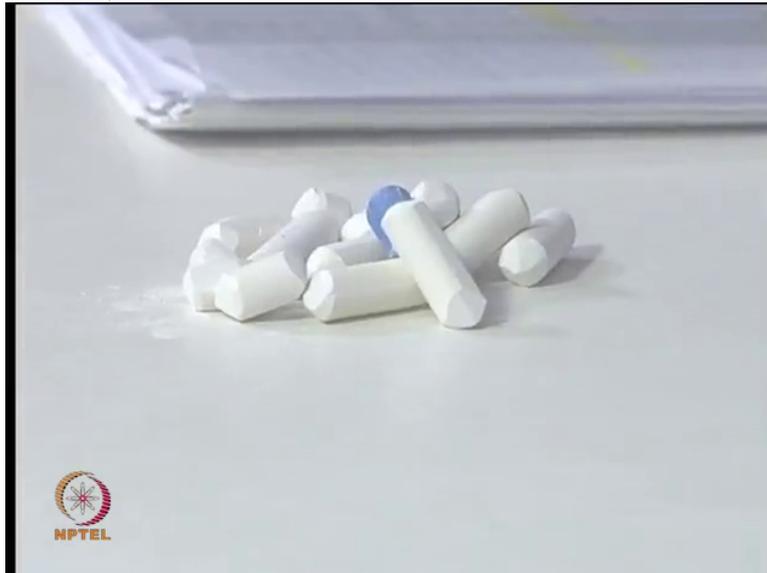Professor: Yeah you come and find out, 18 are there?

Student: (laugh)

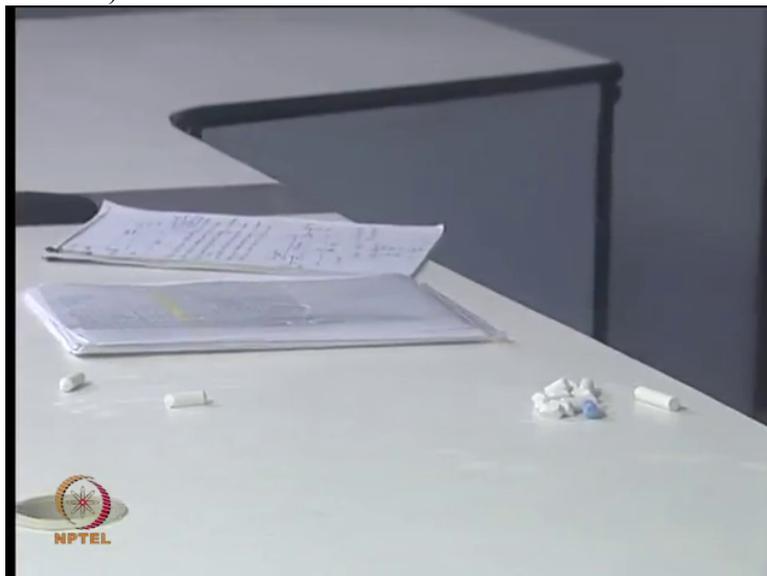Professor: Who said, Abhishek?

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Abhishek told (laugh), yeah see, 18 and all that, your guess but you do not know. That means the mind cannot

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perceive. The easiest one is 1, beautiful. So maximum one is 2.
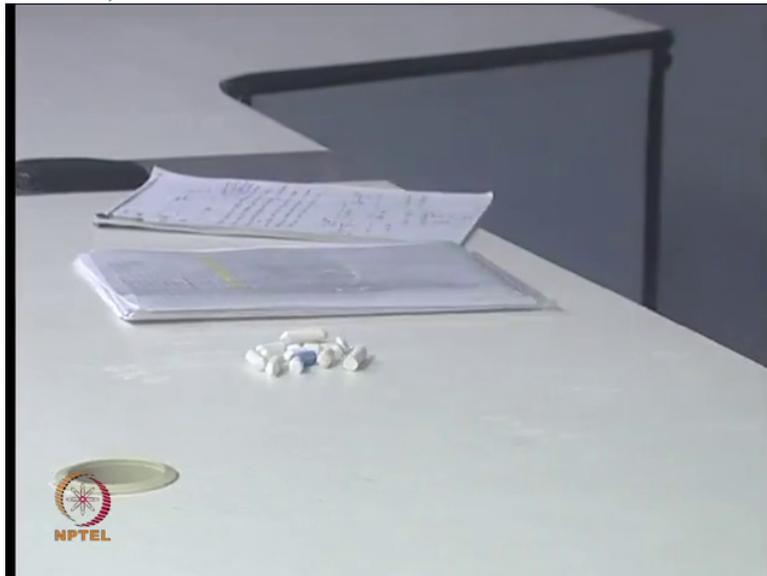
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Ok. May be another, 3. Ok.

Student: Zero is easy

Professor: Ok, zero is easy because we like only zeroes no, so that is why (laugh). Ok so the moment we have more, then it is,

mind cannot perceive.

(Professor – student conversation ends)

That is what is exactly the same problem with mathematics. After some time you feel that everything is mathematics and you have forgotten about what you are talking, you know the problem, actual engineering problem, yeah.

So because you have to now find out what is the technique you have to use to solve that problem where you do not remember what is that problem? So that is why, you know that balance should be maintained by any teacher when you are talking about mathematics.

Even transport phenomena, same thing. Ok, in transport phenomena also, if you explain the physics and then write the equations, you know the diff/differential, most of the time you will get differential equations.

That is also one common thing across all transport phenomena processes. What do you do? Because you have to first identify whether it is lumped parameter or distributed parameter. Lumped parameter is very happy, Ok, why?

(Professor – student conversation starts)

Student: 0:36:19.8

Professor: Whole system is one system only because there is not much; there is no change and all. If it is distributed system, then what you have to take as, take as small element, write material balance and energy balance for that. And integrate between entry and outlet that is why what we call boundary conditions. This is the universal method for all problems, Ok. (Professor – student conversation ends)

But the happiness only comes not by solving them but by actually formulating the problem. Finding out which differential equation is the best and also which boundary conditions are, you have to apply, apply. What boundary conditions to be applied?

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Afterwards it is a mathematical problem.

And mathematics also you have to learn. I am not saying that that they are required, Ok. But if I write one differential equation and then send, and try to solve that problem in 10 classes, then how did you get that boundary condition, how did you get that original differential equation you will forget.

That is what I meant. So that is why always you have to connect there. So that is why we are all again taking very, very
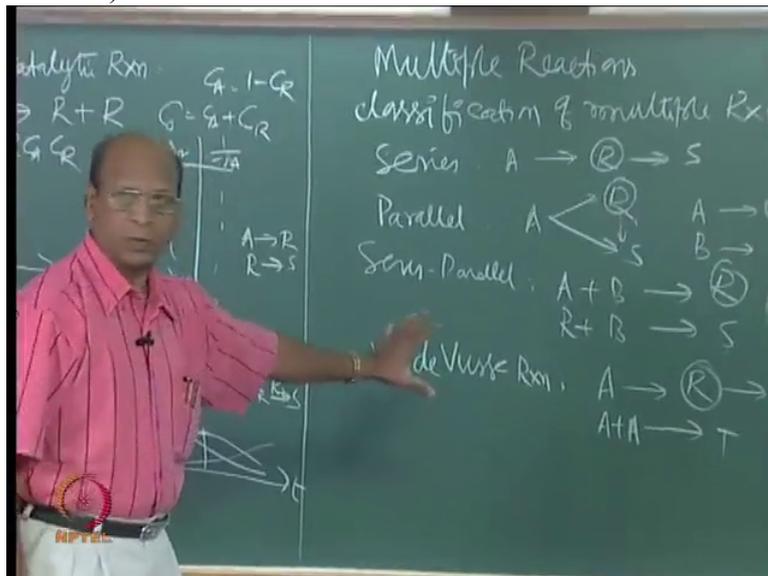
simple problems just to give the concepts first. Afterwards of course mathematics. Once you are experts you yourselves will like to solve actual values.

Because finally the actual mathematical solution that gives me the actual values of how the concentration is changing, when I am talking about transport phenomena problems, or temperature is changing or velocity is changing, that is all no, only three transfers, mass, moment and, mass, momentum and heat. Ok.

So what do you do every time? Every time you solve these, you know either concentration change or temperature change or velocity change and what do you do afterwards? I mean course will be over by that time but actually
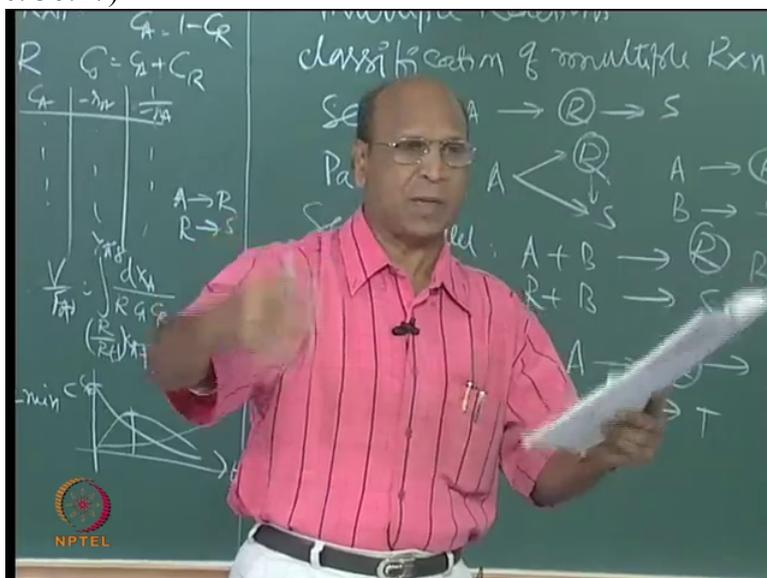
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what for you are doing all that?

(Professor – student conversation starts)

Student: Finding out the flux.

Professor: Excellent. That is the ultimate. I would like to find out what is the flux, either

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that is coming out of a process or whether it is going into the process. How do you find out flux if I give you temperature versus length?

Student: Gradient

Professor: We have our forefathers. Fourier's law. Right. That is all no, that is the flux what you get. And you also have another grandfather, Fick's Law. And you have another grandfather

Student: Newton

Professor: Newton. You see, that is all. I think overall picture of transport phenomena is that.

(Professor – student conversation ends)

That is why I am taking more time in teaching you, because I am teaching entire reac/reaction, entire chemical engineering. That is what is the problem. You know these are the things, that kind of overall picture of any subject you should know. At this point of time, at least.

Because B Tech level I cannot tell because they would have not done transport phenomena yet. They would have not done some other thing. But at this point of time, you put your finger everywhere, right? In your B Tech, some amount of transport phenomena, some amount of control, some amount of heat transfer, mass transfer everything you have done.

That is why I am able to tell you all that because what is the real perspective behind all these subjects and what are the important things what you have to learn from those subjects. That overall picture at least if you do not get after taking a course, I can tell you, either serious problem with you or with us. Because that overall perspective has not come in.

What we require at this point of time is first that overall perspective. What is the use of C R E in chemical engineering, transport phenomena in chemical engineering, fluid mechanics in chemical engineering, or mass transfer in chemical engineering? Ok. Not to get marks. Not to draw McCabe Thiele diagram and finally get 100 out of 100. You may get 100 out of 100 but what is the use?

You know if you are not able to tell how, what is the basis for McCabe Thiele diagram. Ok or Ponchon Savarit method. So those are things what you have to remember, right? It is not the actual values. It is not the actual mathematical equations. No one expects you to remember all mathematical equations, all derivations. But that exposure of where is what and also when do you use what. Good.
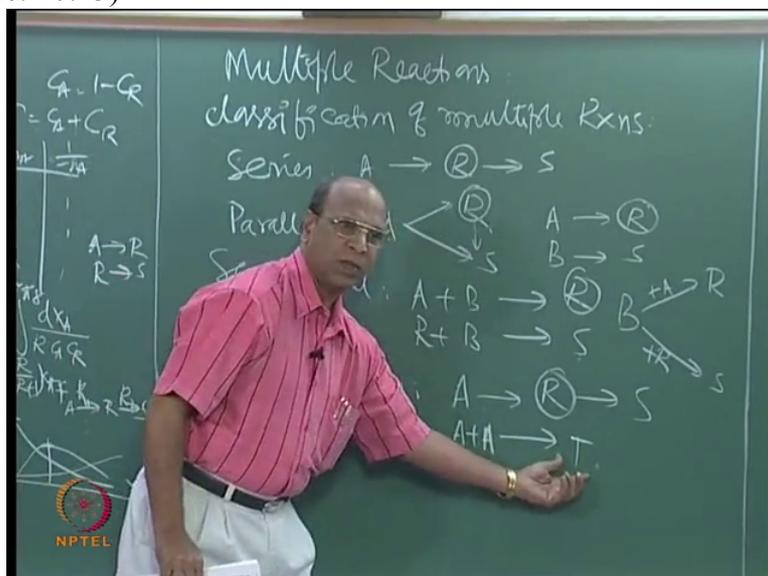
So this is van de Vusse equation. What is the problem here? I have
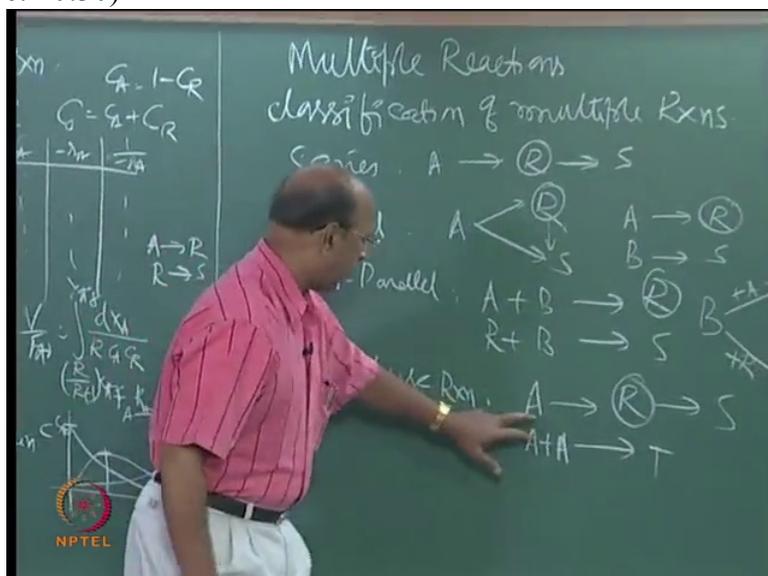
A going to R, R going to S, it is a series reaction. Then I have a parallel reaction here. A is combining with another A to give me a side product which is not required for me. Now that means I have to minimize that.

So I have to minimize, the problem is, I have first order here, because all elementary we said. And I have second order here. Second order reactor will consume more and more A, because C A square, right? So that is why. Even though it is second order reaction how do I now stop that reaction as much as possible?

That is why we have the best techniques again called catalysts. If you are able to develop a catalyst or take a catalyst where this is inhibited and this is accelerated,
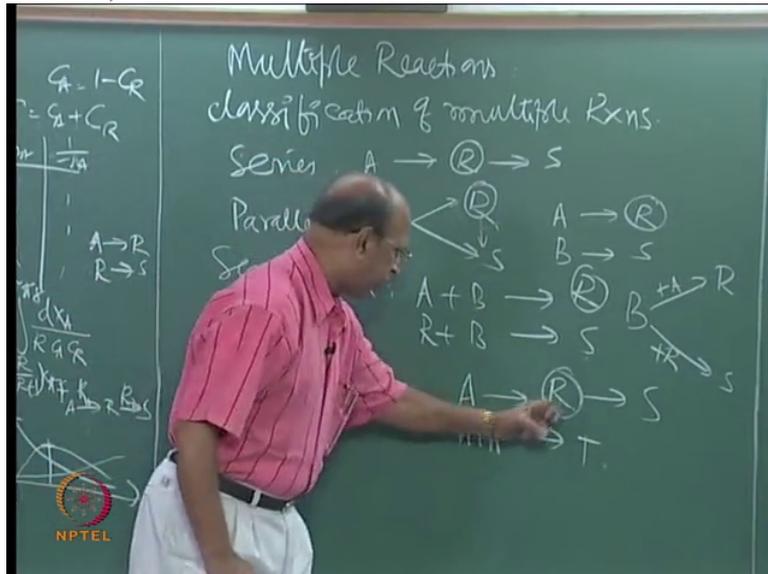
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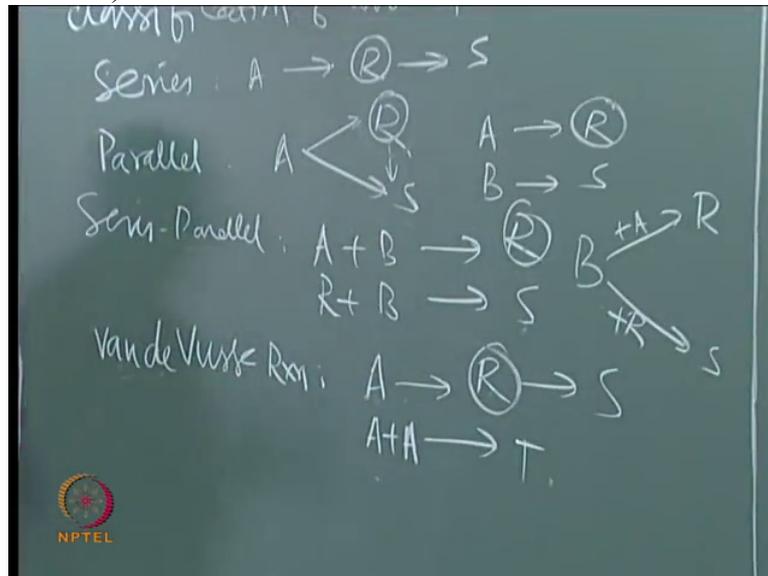
you do not have to do both. At least inhibit this, this will automatically accelerate. If you are able to do both, that is excellent. That is why catalysis also is important. If you are able to find catalyst it is excellent.

You do not have to do; your mathematics will be very simple again. Because as far as catalyst is concerned, this is suppressed totally. You do not have to do anything with that. Only you have to calculate using that series reaction, right? So actually this is one of the examples where recycle reactor will give you more R. Under some conditions. It is not all conditions. Ok.
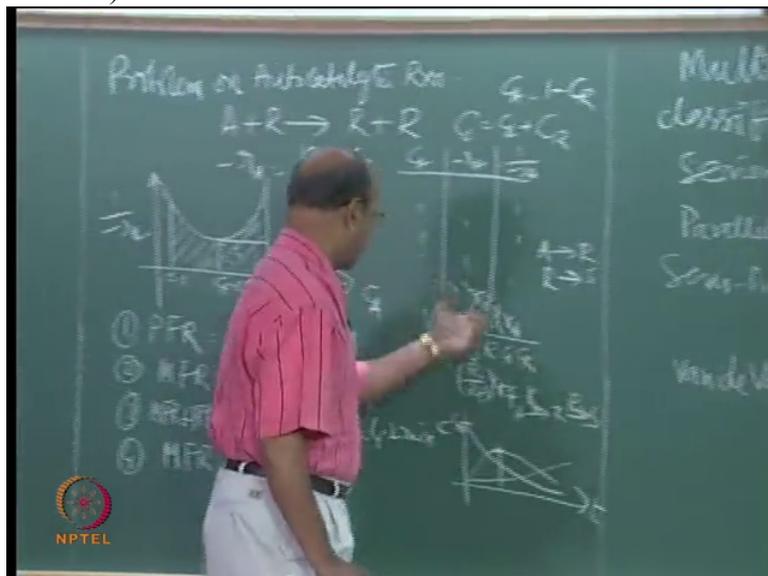
So when I substitute this and this and
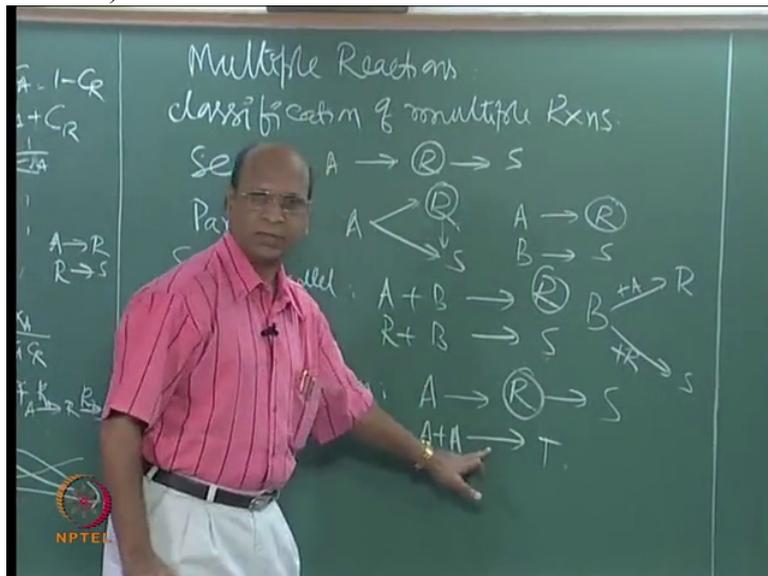
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then try to find out, you know the yield

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using these design expressions, then you will have some conditions where, because this is k
1, k 2, k 3, no,

k 1, k 2, k 3, depending on the values of these k 1, k 2, k 3, under some conditions, under some recycle rations you get the maximum for this R. This R is not the recycle ratio, Ok, this R is the product.
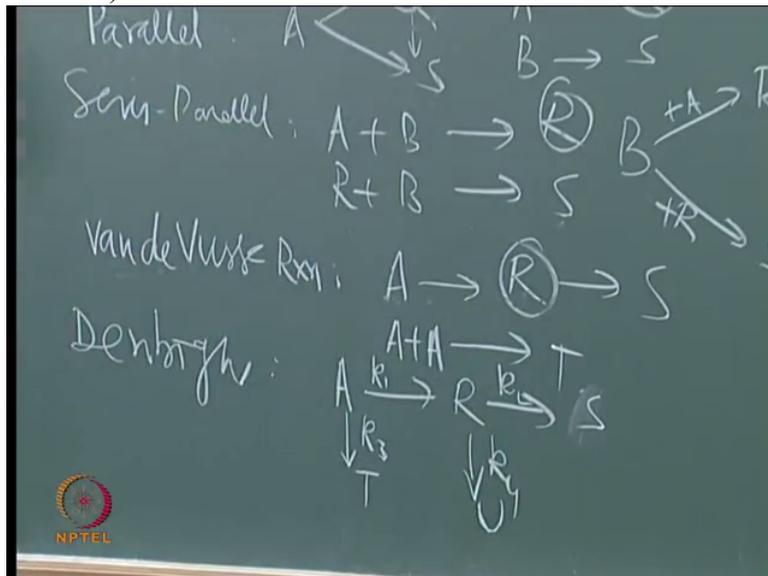
Another famous equation is the Denbigh equation. You know Denbigh, no? Yeah, I think you have to remember all these people. This is also important. Ok, so I have here A going to R, R going to S, then I also have this A going to T and this is going to some U, yeah. So this is series
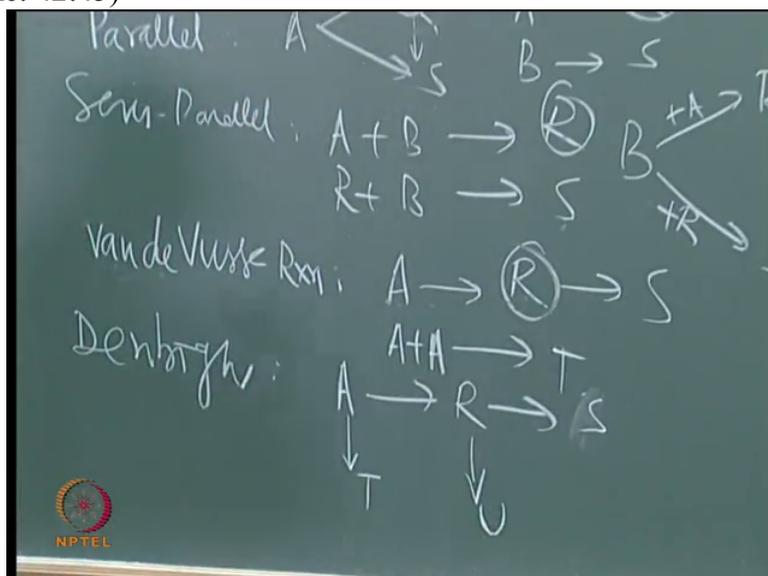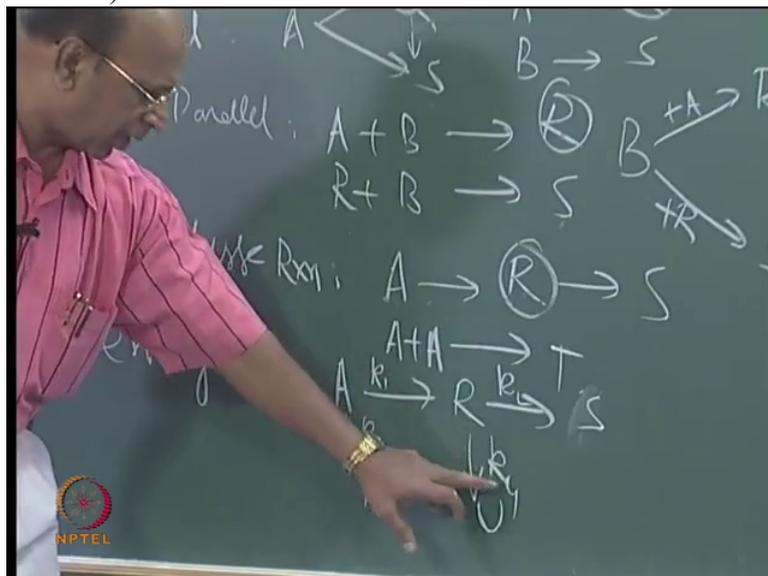
and parallel combination.

If, Ok, if this is k 1, k 2, k 3,

k 4 and if k 3 equal to k 4 equal to zero then I have only series reaction, right? And the other hand, if I have k 2 and k 4 equal to zero, then I have only parallel reaction. All kinds of combinations you can get there. But here, sometimes either S is the desired product or sometimes
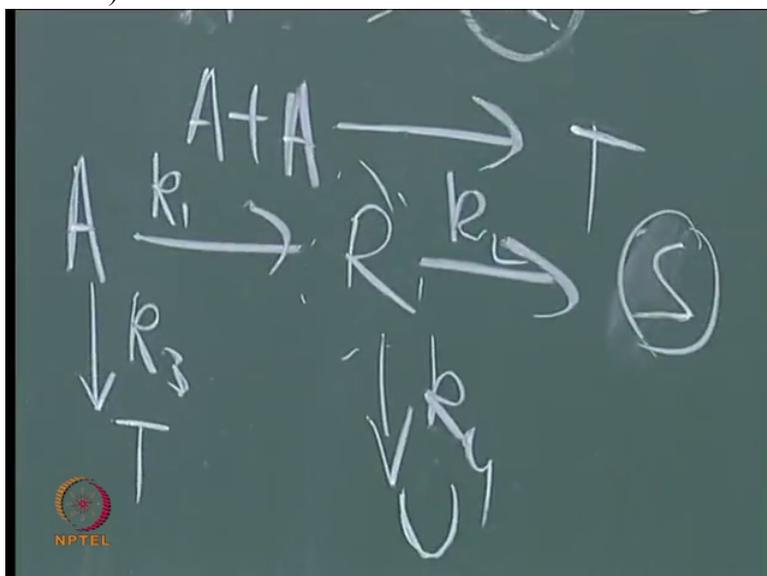
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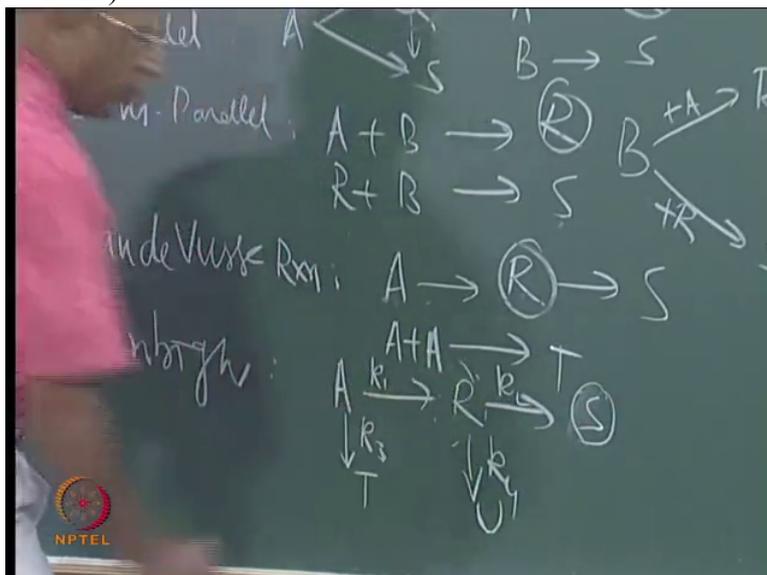
you may have also R desired product.

R is more challenging, correct no? R is more challenging. Why? Because this R goes to S and also R is going to U, whereas here anyway R is finally going to S then I have to suppress this equation and this equation, this and this. That is all.

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Ok

But now if I have R as the desired product then I have to stop this reaction, stop this reaction, stop this reaction. Three reaction, Ok, I have minimized, stops means I have. If you are able

to get a catalyst particle where you can only produce only this R and all other things are suppressed, excellent.

But life is not that easy. You know, life is easy only in movies and in novels. All these things are not that easy problems

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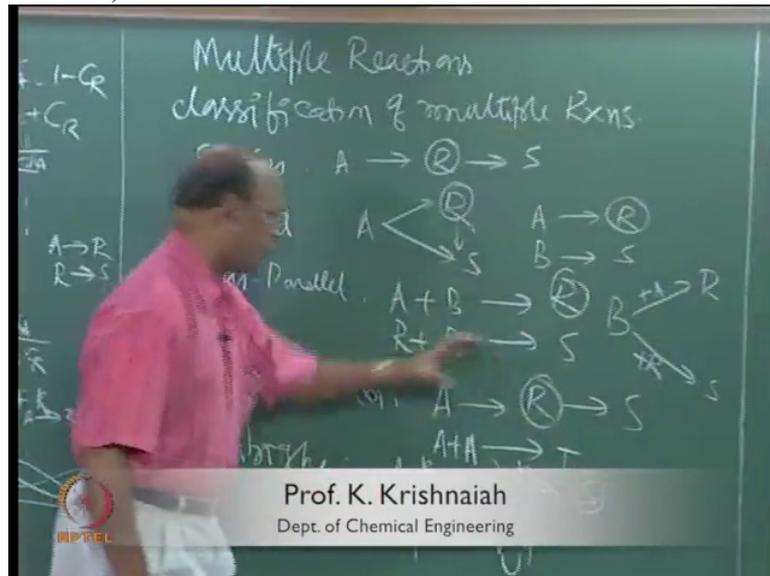
the way we talk and that difficult thing will come to you only when you try to solve the problem. So they are not that difficult problems again.

But difficult and all that is relative. If you do not do any problem everything will be different, difficult. If you have done some problems things will be easy. So that is why please try to do problems. I think we will stop here. Tomorrow we will discuss about the definitions of yield...