Aspects of Biochemical Engineering
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Lecture – 20
Reactor Analysis IV

We will come back to my course aspects of biochemical engineering now, I think this is the last part of a reactor analysis we discussed the theoretical portion of the how to how to analyze the reactor and this is then we, last 2 lectures I discuss several numerical problems just to have very clear idea about the reactor analysis and this is the last kind of last lecture and here I shall concentrate on couple of problems and how we can have better idea on this analysis of the reactor. You know that if you look at this again here we will consider.

Now in this lecture, I am going to consider all the all the different type of reactor batch process batch reactor will consider will consider CSTR will consider plug flow reactor we shall show you that in a in case of CSTR and plug flow reactor if you increase the flow rate how is it going to affect in the system how if you increase the concentrate initial concentration of substrate how it influence on the process though this I shall I shall I shall try to discuss the another thing very another very interesting thing also I try to incorporate that if you club this you know CSTR with plug flow reactor how we can do the analysis. I hope by this lecture you can have very little bit clear cut idea how we can do the reactor analysis.

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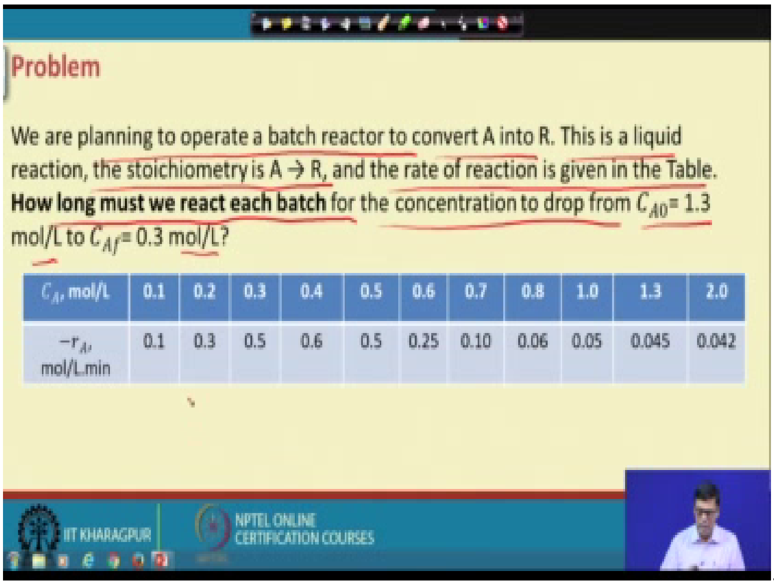

To start with this let me start with the batch process first now if you look at here that that we are planning to operate a batch reactor to convert A to R and this is a liquid reaction the stoichiometry is A to R and the rate of reaction is given in the table how long must we react in each batch for the concentration to drop from C A is 1.3 mole per liter to point 3 mole per liter and this is the data that is given. If you look this problem is apparently is similar type as I discussed in the last lecture class and let us see how we analyze this problem.

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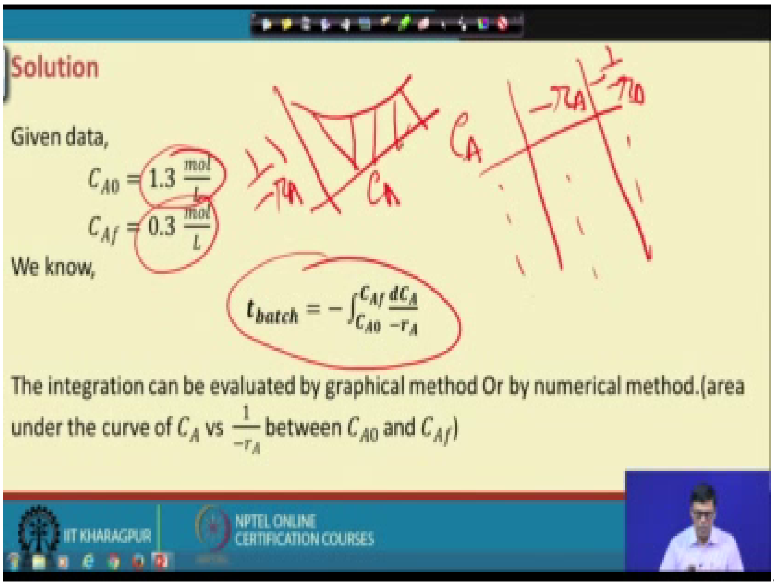

Now what is the, is what we shall have we are planning to do we want to reduce the initial substrate concentration from 1.3 mole per liter to 0.3 mole per liter and. This is the T batch that A equation that we have already we know. Here what we have we have the data of ca and also we have the data of minus R A. Here we can also find out minus R A that different value we can we can we add different value, we can do that then we can plot that minus R A versus C A then we have this plot we can calculate this what is how we can find out the time required for a batch process you can easily calculate

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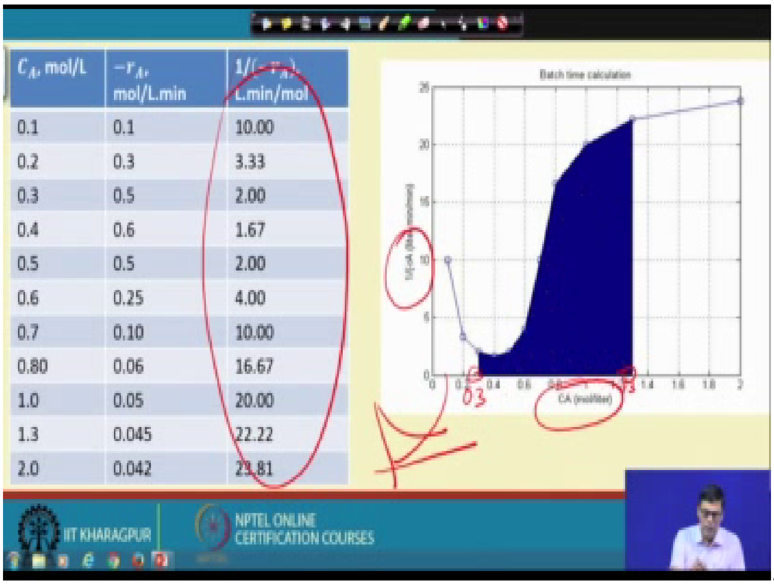

Now this is how we calculated the data that is 1 R A is 1 R A 1 by R A this is this is the whole data that, we can calculate and then if you put this is the figure this is this is 1 minus R A by C A, this if you put now this is this is this pattern if you can see it is a little bit different as compared to the previous pattern previous pattern more or less we have the correlation is like this, but here it is like this.

You know that here what is happening that here this is 1.3 now this point is 1.3 the 1.3 to 0.3 this is 0.3, then what is the time is required. If you, if you calculate the area under this curve then area under this curve then what is coming this will come around 12.7 minutes this will come around this area under this curve will come about 12 point this is the 12.7 minutes that is the time you can you can calculate you can find it out.

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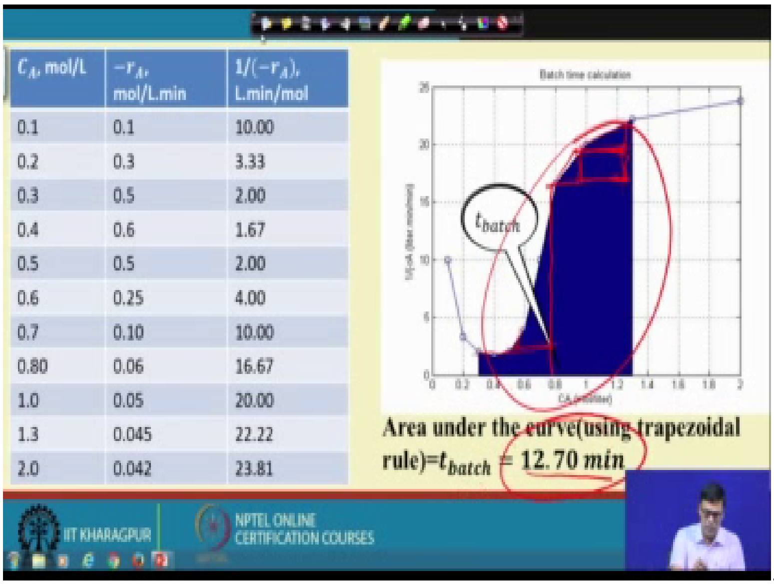

It is it is very easy to do that because you know. Only that you have to you have to again I am telling you that you do not have to count the number of square of the centimeter graph paper because this is very laborious, but if you want to solve it you have to do it very try to do it very easily you have to make a rectangle like this that you know that. You can consider this as a triangle you can consider this is rectangle am I right and this is again is a triangle then it is a rectangle now again this you can more less you can consider it as a triangle then you can consider this rectangle.

Approximate value because I because graphical method exact value it is very difficult to find out, but you can find out the approximate value time required for the batch process.

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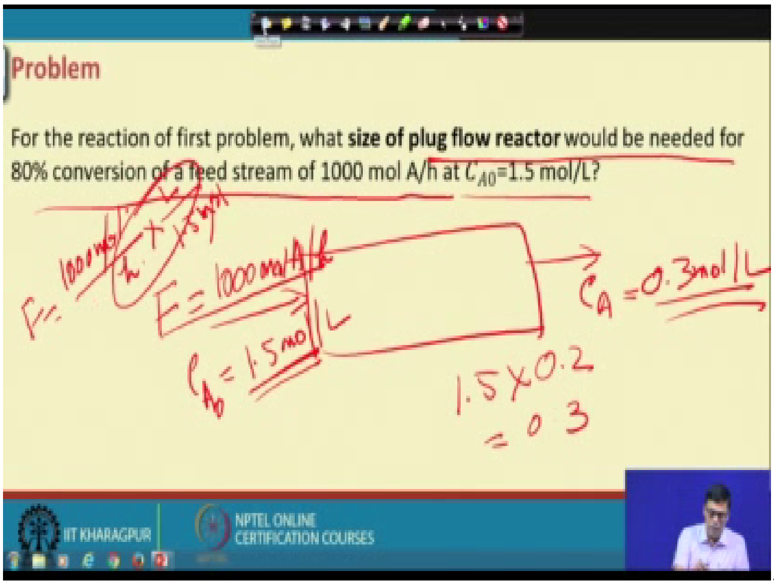

Now for the for the reaction of the first problem what size of plug flow reactor would be needed for 80 percent 80 percent conversion of the feed stream of 100 moles of A at C A 01.5, now here I want to point out that in my last presentation I forgot to day discuss similar type of problem on plug flow reactor I hope it is similar type of problem. If you understand that this also this you can solve it very in that also you can understand very easily now here that what is what is there saying suppose this is the plug flow reactor that they are saying that this is this the input this is the output now what is the input that we have here flow rate is equal to 1000 moles of a per hour am I right and what is C A 0 C A 0 equal to 1.5 mole per liter.

This is this what size, 80 percent conversion 80 percent conversion means how much substrate that remain that 20 percent. 1.5 into 20 percent that is 0.2 that is equal to 0.3 then here the ca value will be what 0.3 mole per liter am I right. We shall have to find out what size of the plug flow reactor is required to reduce the substrate concentration 1.5 moles per liter to 0.3 moles per liter and the flow rate is hundred moles of paper now, here I want to again one thing I want to point out that f is given in moles per hour am I right F is given in hundred mole per hour per hour am I right. If you want to convert it per volume, what you can do you can divide by 1.5 C A 0 at the mole per liter. Mole will cancel, you can find out liter per hour this is you can easily find out the volumetric flow rate you can calculate like this.

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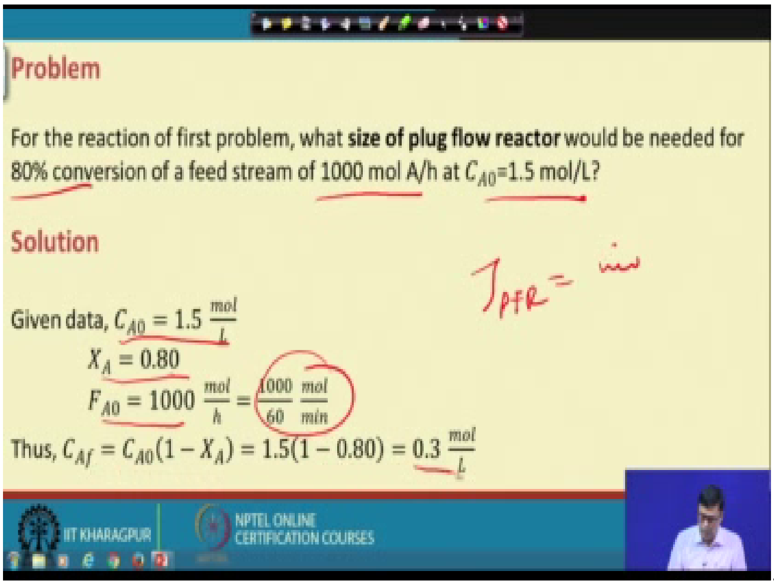

Now, this is as I as I pointed out that first you have to write what are the things given in the problem that these are the things given C A 0 is 1.5 we you see that 1.5 is the C A 0 and X A is the 80 conversion is the 0.8 and F A 0 this is 1000 moles of a per hour this you can convert per unit this is very important because you know that this is suppose here it is just a minute is some tau plug flow reactor you calculate in minutes. This flow rate also it should be in minute otherwise there will be some error in calculations now C A F equal to this is 0.3 this I have already shown you I do not like to explain further.

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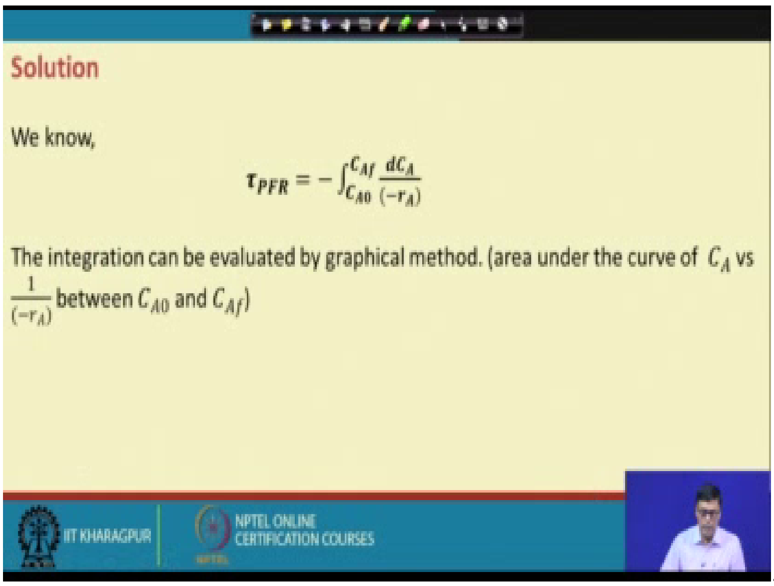

Now the equation is that equation for this is the tau plug flow reactor is this and the same as your batch reactor the integration can be evaluated graphically under the carve C A versus 1 by R C A 0 to CAF .

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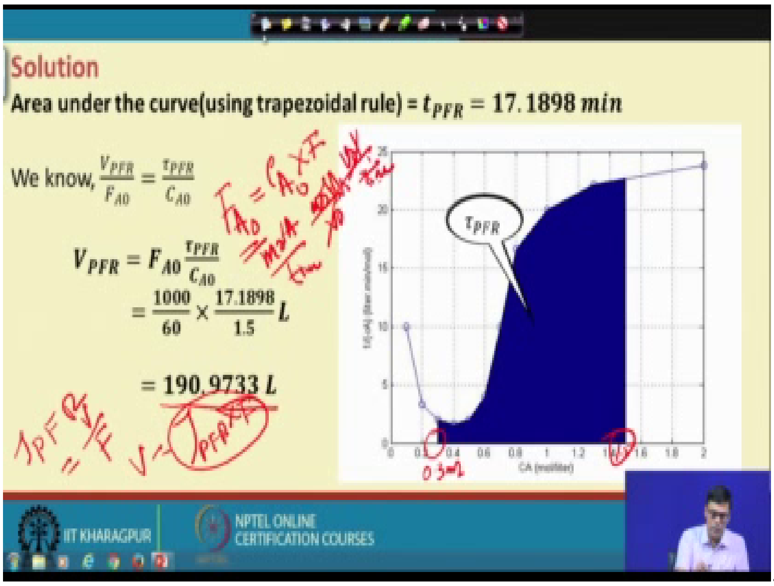

Now, this is this is the carve that we have this is 1.5 this is 1.5 t his is 1.5 this point and this is 0.3 this is 0.3 mole per liter. Area under this curve I showed you how to calculate and then you find out tau see you can find out tau plug flow reactor once you know tau plug flow reactor then tau plug flow reactor is what tau plug flow reactor is equal to what you can write equal to V by F am I right what is what is the F I have already shown you F V equal to tau plug flow reactor into F. You can find out the volume of the reactor now here in this problem and it is been solved in the similar way only they have shown that F A 0 F A 0 is equal to what C A is 0 into f am I right what is the F A 0 mole of a per unit time am I right. This is equal to what mole of a per unit volume this is volume per unit time. This volume will cancel, mole of a versus per unit time.

This is same it is like this if you if you divide by this you will get the volume that you know the same thing you will get. Volume V by F equal to tau plug flow reactor this is similarly we calculate here and find here that you can you can find out the volume of the reactor is coming plug flow reactor is come one 190.7 liters this is how we can calculate this is a here tau plug flow reactor has been calculated with these I forgot to mention this 17.8 minutes. You can easily do the calculations here now next problem.

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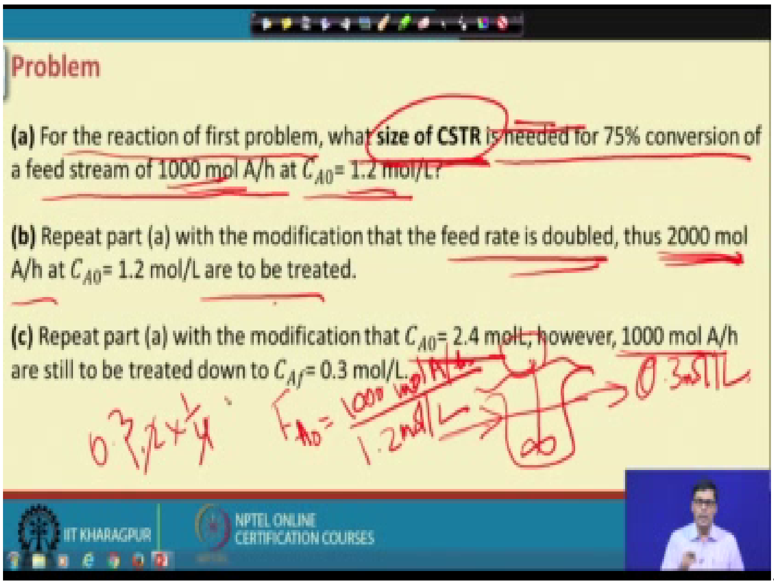

Next couple of problems are very interesting that if you if you look at for the reaction in the first problem what size of previously we also discussed about the plug flow reactor now, we are talking about the CSTR what size of CSTR is needed for 75 percent conversion of feed stream containing 100 moles of a per hour C A is 1.5. It is basically like this is a continuous process we have to continue a stirred tank reactor like this. Here what is happening this is here it is to 1.2 moles per liter.

75 percent conversion there how much it remaining one fourth 1.2 into 1 fourth is coming around 0.3. Here is the 0.3 mole per liter am I right. This reaction for 75 percent conversion and what is the F A F A value F A 0 value is equal to 1000 mole a per hour this is given here. You have though you have to find out what volume of the CSTR is required now repeat the first part the modification is the feed is doubled as I mentioned the if the feed rate is doubled because initially it was how much one thousand moles of a per hour now if we make a 2000 moles of a per hour then what will be then what will happen that that we shall have to find out now next problem next problem that C A 0 value was 1.2 now if you increase to 2.4, but you know flow rate F A 0 is same then what will happen to this particular size of the reactor. The dividend different way we want to solve the problem and try to find out how it effects the process .

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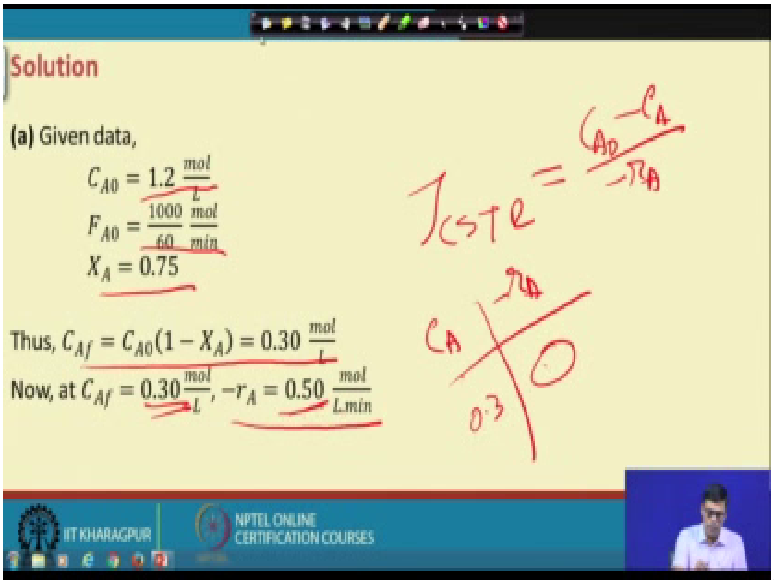

Now, in this problem the C A 0 is value is given F A is given we only go convert in per minute because this is given per hour and conversion is 0.5 the CAF I have already shown it is 0.3 and C A now CAF and. RA RA we can I minus RA we can a 0.5 how we can find out tau CSTR equal to C A 0 minus C A minus R A.

Now, in this problem because if you if you this is the repetition of the previous problem we have we know we have the we have the figures the C A V.

ERSUS minus RA, since our substrate concentration is 0.3, We know where 0.3 what is the rate of reaction this is about 0.5 from the table we can find out this is about 0.5.

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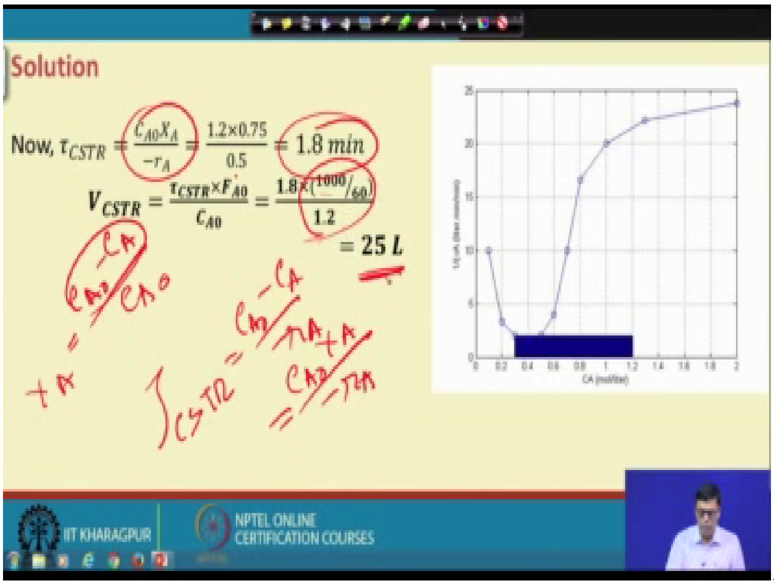

Now, now as I as I mentioned tau as I mentioned tau CSTR is equal to C A 0 minus C A minus R A am I right. This is equal to also we can consider C A into X A minus R A why because the X A equal to C A 0 minus C A by C A 0. I can find this is equal to say the multiplied by this. This is how it has come. We can we can put this equation 1.2 point 4 7 5.5 then we can easily find out the volume of the reactor once we know the volume then we know the we can I have already shown you how to calculate the volume volumetric the flow rate then you can find out the volume of the reactor is 25 liters though this you can.

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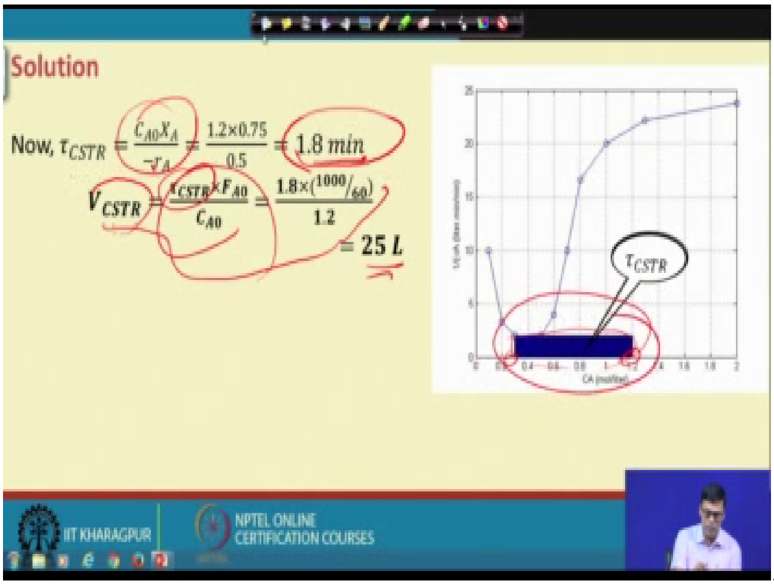

You can solve of graphically also that you have already drawn this plot. This is 1.2 in this graph where this is 1.2 is there and this is 0.3 is there then this is a simple rectangle now I right and length into breadth if you multiplied you will get you do not have to do this numerical and it is a simple throw graphical method also.

You can find out the time required for this once your required time then you put this value here time value here and this equation you can put it that this value put this in the equation you will find 25. This time this equation here you use this equation, but with the in place of using this equation through capital method also you can find it out now.

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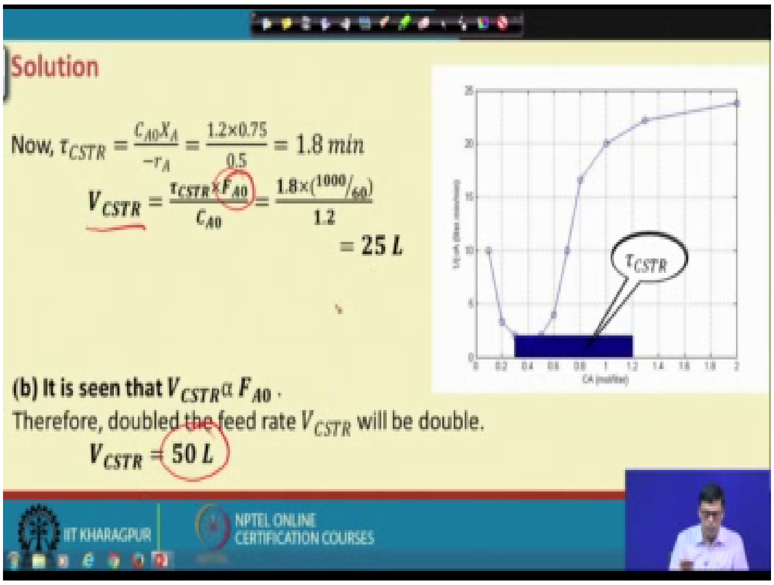

Now, it is it is seen that that if volume of the reactor is proportional to F A 0, now therefore, doubled the feed rate the volume of the this 50 this 25 liter into 50 liter. How you can how you can justify that how we can justify that this is volume of the reactor volume of the reactor you can see this is in this problem this here you find out the volume of the reactor is proportional to this if you keep other constant then if you make a doubled then naturally the volume will be doubled that is seen this proportional to raise this is doubled then this volume will be if feed rate is doubled then volume also will be doubled that is what we expect now.

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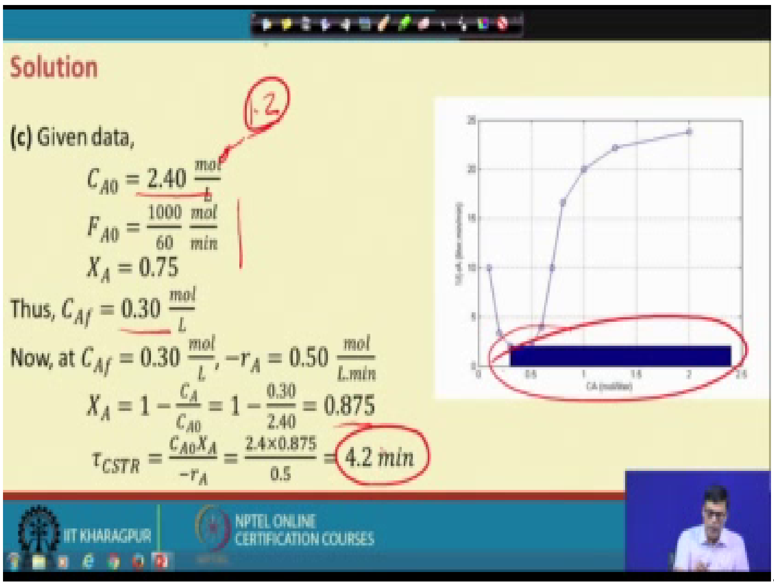
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Next problem that we have if the concentration is doubled the initial concentration is the previously it was 1.2, but now we had increased to 2.4 other the other remain constant this is a 0.3 and other thing then you put this that then conversion efficiency also changes and then we put this equation then we find out this the time required in CSTR is 0.4 point 2 minutes, but a say we can we can we can solve this then graphically also if you if you know this is 2.4 and this is point 3. You the area of the rectangle you can find out and that is also will come at 4.2 minutes.

Now, once we find out this time we can easily calculate the volume of the reactor because this we can easily calculate because the volume of the reactor is equal to TAU CSTR F A 0 into C A.

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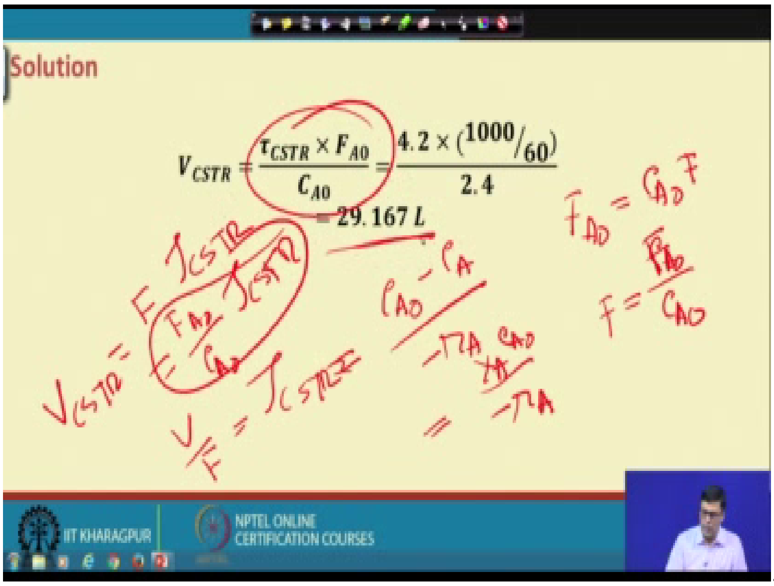

I hope I can I can explain that because the tau CSTR is equal to as I mentioned C A 0 minus C A minus R A am I right. Here you see this is equal to X A into C A. What is F A 0 F A 0 equal to C A 0 into F and what is TAU CSTR tau CSTR equal to v by f am I right . So, what I can the write that that here oh what we can write the volume of CSTR is equal to what and the f into f into tau CSTR am I right now what is the F equal to F A 0 by C A. I can write this is F A 0 by c a 0 into TAU CSTR. This is how it has come you known this is how we have written here and only we put the value here we can get the volume of the reactor, we can easily calculate the volume of the reactor here.

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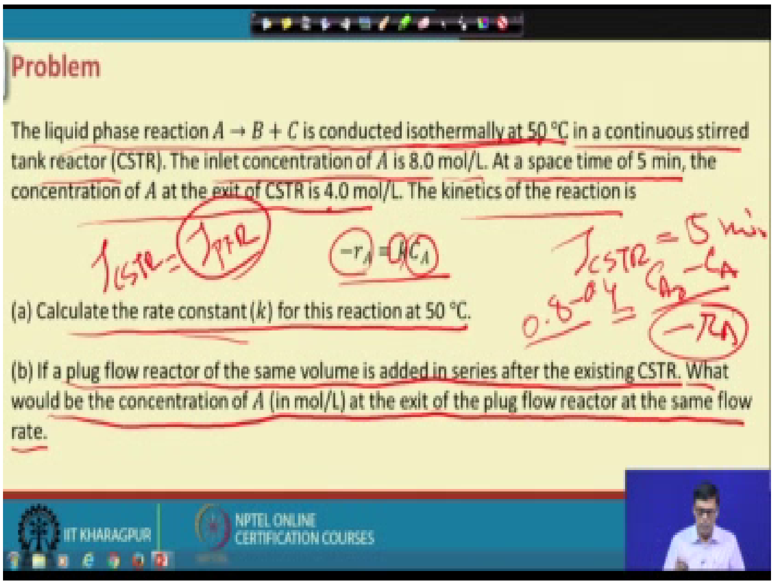

Now, last problem that I am going to discuss this is also very interesting now before I go to the problem let me discuss some something that I try to explain before also that suppose we have a plot minus RA versus CA am I right and we have plot like this.

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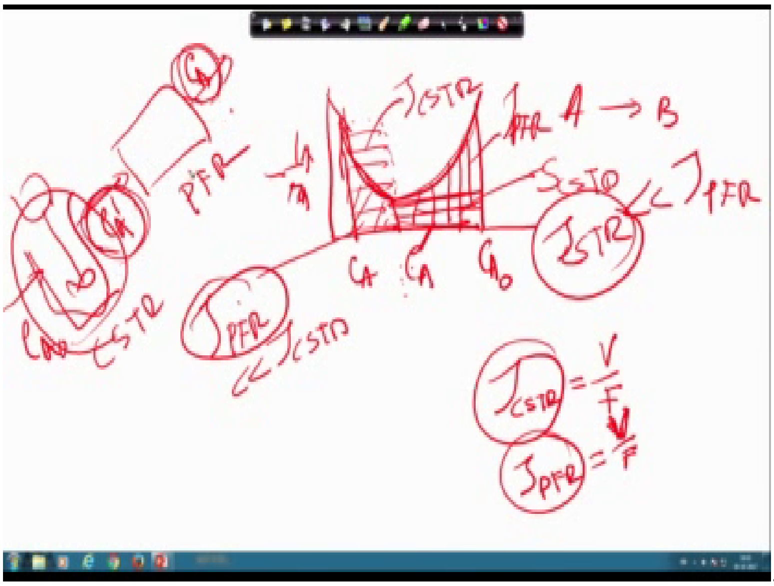

Now, suppose I want to this is the same reaction A to B and here this is C A 0 C is 0 and we can we can we can this is the let us assume C A this is C A dash am I right now.

You have 2 pattern you know what I wanted this I discussed before also we have 2 different patterns now if you have this patterns in this particular reaction then same type of reactor may not be suitable for the system because one reactant may be suitable for conversion of C A 0 to C A dash and another type of reactor may be suitable for conversion of ca dash to C A. If you consider this C A 0 to C A and our what is our target our target is if we look at TAU CSTR is equal to V by F am I right and TAU plug flow reactor that also equal to V by F. We shall have to find out under what circumstances this is minimum this is minimum that is a logout selection now when C A 0 conveyed to CA the area under this curve this curve this is equal to tau we have a plot minus RA versus CA am I right and we have plot like this.

am I right TAU CSTR, but the area under this curve is tau plug flow reactor so; obviously, TAU CSTR here is much less as compared to tau plug flow reactor. What do you what is our selection for this time of reaction our selection goes to TAU CSTR, but here it is something reverse here you see the when CA dash to CA then area under this curve area under this curve will be tau plug flow reactor, but when you consider go for plug the CSTR this is tau CSTR.

Naturally this is much less as compared to TAU CSTR. Our choice is TAU plug flow reactor if you conversion of C A to C A dash to C A. Our choice, if you if you look that reactor that our strategy should be like this that initially this should be CSTR and followed by plug flow reactor those this is CSTR this is plug flow reactor this is C A 0 to C A dash and this is C A know why I told all these things because now coming problem that we are also going to deal the similar type of things only the thing is that how we can find out that if you operate the CSTR how we can find out how much when substrate is converted and if you if you followed by say plug flow reactor how much substrate will be converted. What is the value of C A dash and what is the value of C A that we are going to convert. This is this is like this that in the liquid phase reaction A to B plus C is conducted isothermally means temperature remaining constant at 50 degree centigrade at continuous stirred tank reactor.

The inlet concentration is 8 moles per liter and space times 5 minutes space time means tau CSTR am I right tau CSTR is 5 minutes the concentration of the a the exit stream is for 4 the kinetics is given here. Calculate the K constant we can do it very easily because tau CSTR is equal to what that I can I can I can I can write C A 0 minus ca minus RA am

I right what is this CA 0 value 0.8 0.8 this is what is C A 0.4 and what is the tau where this is the TAU CSTR value 5 minutes. We can easily calculate the value of RA. That is exactly once you know the RA value then we know the K the CA value that is for 4 under steady state condition. We can easily calculate the value of K. It is the it is the it is done it can be done very easily that a rate constant we can calculate very easily now next part is that if a plug flow reactor of the same volume is added in series after the existing CSTR what will be the concentration of a at the exhibits exit of the plug flow reactor the. Here I want to want to state only 1 thing that since this is connected with the same volume same flow rate I can assume now tau CSTR is equal to tau plug flow reactor. Only we shall have to find out the at that particular situation what will be the concentration of the substrate at the exit stream from the plug flow reactor this is the problem.

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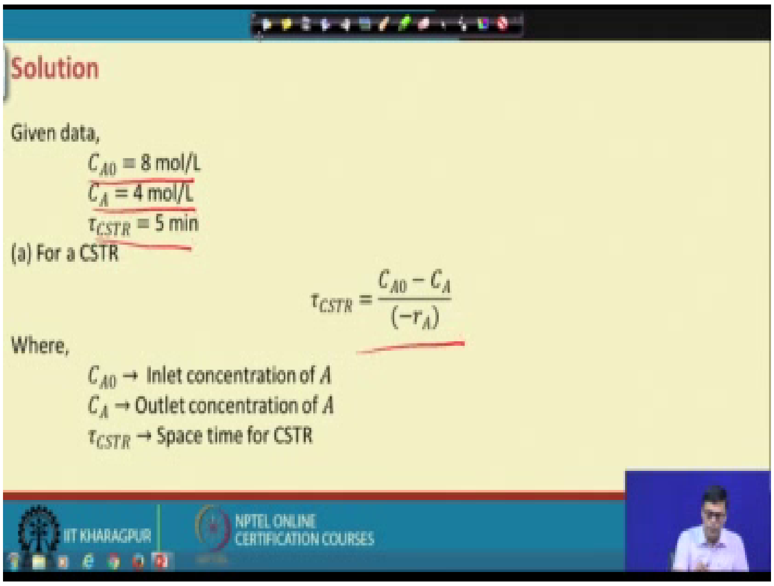

Now, this is this is what is given in the problem C A 0 equal to 8 moles per liter and C A is the 4 mole per liter CSTR is 5 minutes. This is the equation that we have now.

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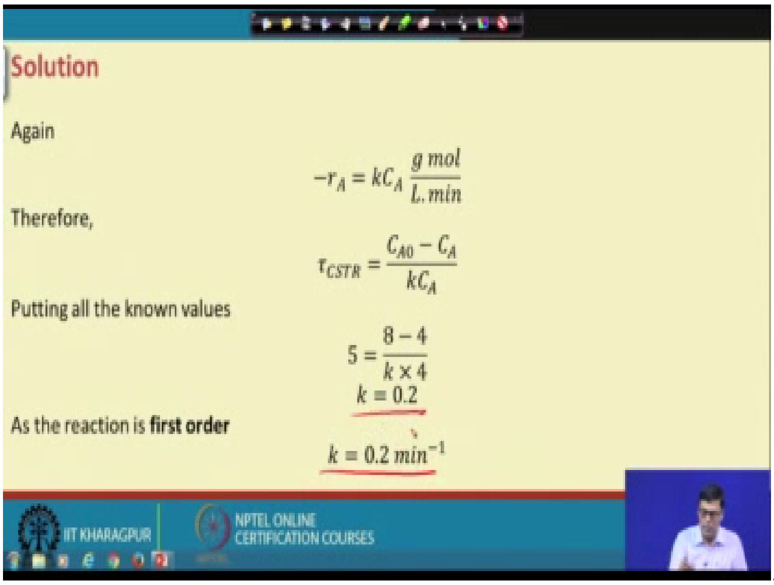

If you put this equation you can easily find out you can easily find out the value of K value of K be is the if we assume, but this is first order reaction. It is minute inverse the unit will be minutes inverse now.

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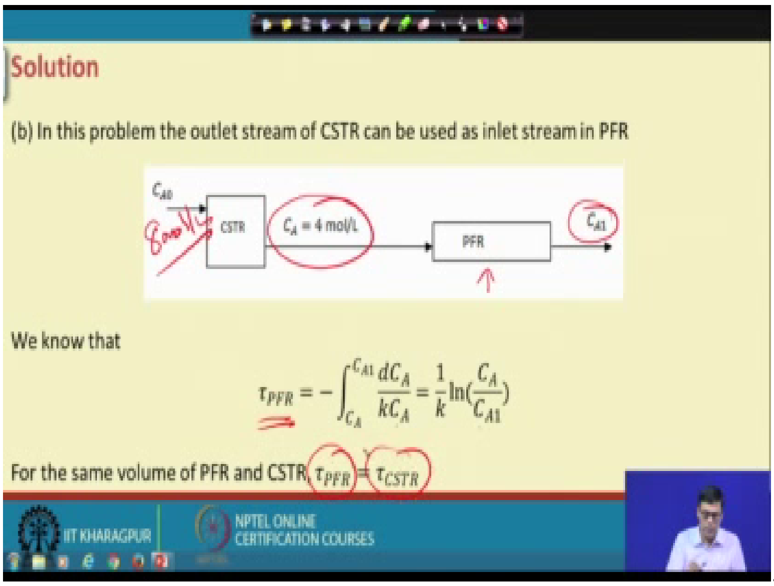

Now, in the second part of the problem that you know here we have 8 mole per liter am I right 8 mole is convert to 4 moles now if when you same volume by yourself plug flow reactor we use here and what will be the C A 1 value that we still have to calculate and what is our equation that we have tau plug flow reactor equal to D minus DCA by K into

CA We can we can easily solve this is equal to like this ln CA by CA 1. This is that as I as I the same volume is used to I can I can assume the tau plug flow reactor equal to TAU CSTR .

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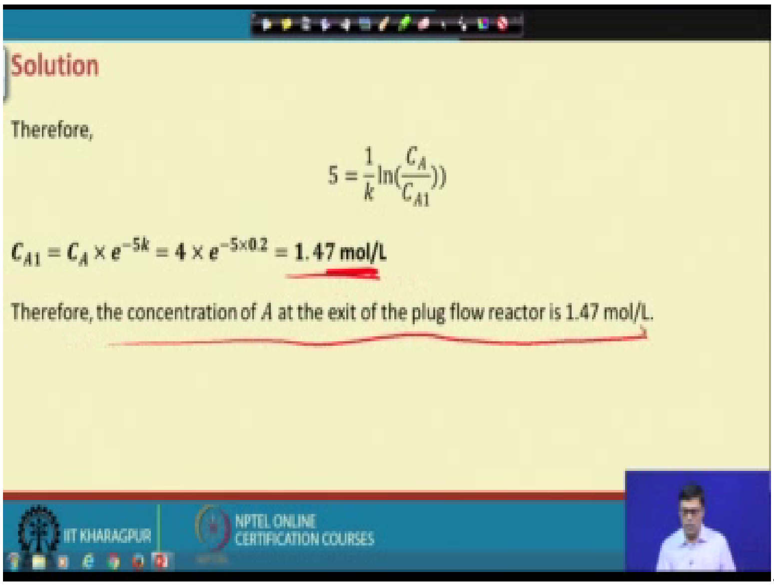

Now, the we can write 5 equal to 1 by K now if you if you look at this equation that ln CA what is CA is 4 and CA 1 we have we shall have to calculate K value also we have already determined. We if we put all the values here then we can we can calculate the CA value and which is coming around 1.1 0.4 7 mole per liter. Therefore, the concentration here the exit stream of plug flow reactor is one point 4 7 mole per liter. In this in this lecture I try to point out that you know that by using the batch process using the if you learn a particular batch process and try to find out the rate constant as the different substrate concentration how we can find the batch time that you can calculate and from this same data we can also calculate that that what is the time required for the 80 percent conversion 75 percent conversion or 95 conversion in the plug flow reactor.

Same type of thing we can do in case of CSTR, but at the same time if you wanted to increase the flow rate what will affect on the process or if we increase the substrate concentration of this initial substrate concentration in the in the continuous process that how is going to affect the process. This I i showed in this problem and finally, I discuss when CSTR club with plug flow reactor how you can analyze the process and. We can we can calculate the substrate concentration in the existing both in the CSTR and the plug flow reactor very easily provided we have all the all the information that is available in this problem that we can determine the here the different parameter different parameters and put these values and then we can find out the concentration of the substrate at the existing. I hope this you will be you will be having very clear idea for the reactor analysis and I request all of you please put your pain to it you try to solve in is individual problem by yourself, that we can have clear idea on this process.

Thank you very much.