Course on Industrial Biotechnology
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Mod02 Lecture08
Reactors Analysis (Contd.)

Now I am going to discuss about the reactor analysis, the continuation of my previous lecture. Now we have in the last lecture I try to show you that how we can analyze the reactor and I told you the reactor basically, it can be divide and classified into 2 types one is call batch reactor, another is continuous reactor and batch reactor we take the material at a time let the reaction take place and after the reaction is over you take out the material in between there is no input and output in the system from the system, but in case of continuous reactor mostly , there is a continuous inflow and outflow in the system something is coming in and something is going out from the system and two type of process we have we came across, one is call continuous stirred tank reactor and plug flow reactor and in the last class, I try to point out that plug flow reactor. Why it is used for the product inhibition reaction. So today I want to discuss some problem related to the reactor analysis.

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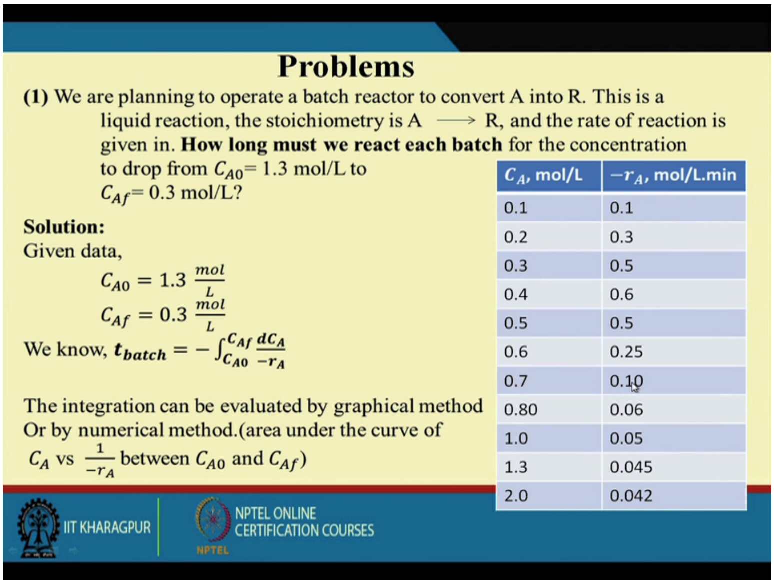

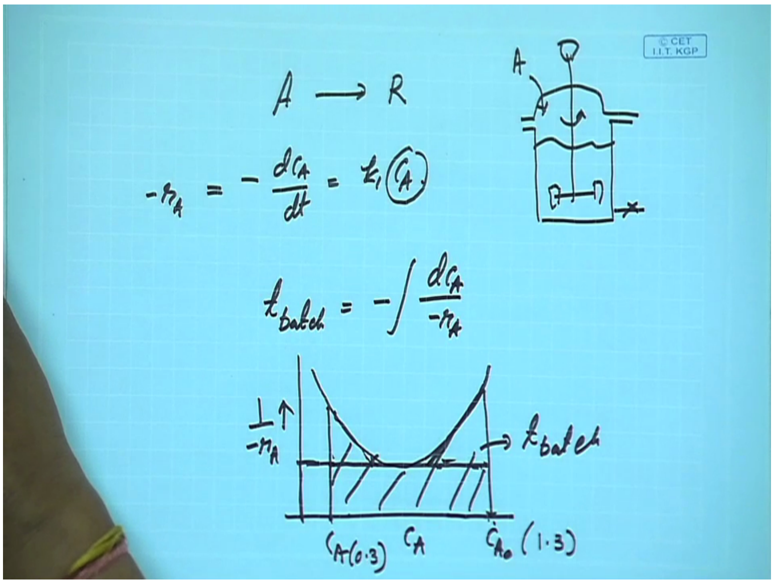

Now first problem I want to discuss that is we are planning to operate a batch reactor to convert A into R and this is a liquid phase reaction, stoichiometry is A to R, A to R means 1 mol of A is converted to 1 mol of R that is the stoichiometry A to R and the rate of reaction is given (how long must the reaction) how long must we react each batch for the concentration to drop from 1.3 mols per liter to 0.3. So we shall have to find out the time of reaction that we required in the batch process.

So batch process basically, it is like this that, this is the reactor, we take A and after the reaction is over we take out all the material (())(2:40) of the system. So here the problem what they have done that a, they determine the substrate concentration that at different substrate concentration what is the rate of the reaction, because the when you talk about the rate of the reaction that the d CA by dt is equal to k1 into CA. Now so it depends on the concentration rate of the reaction, it depends this is equal to minus rA. So this by this is directly (()))(3:22) the concentration. Here we can see that rA as the r that the CA is changes and rA is calculated. Now so what we have derive the equation we can remember the tbatch is equal to minus d CA by minus rA. Now here we have seen that if you plot 1 minus rA CA equal to then if you have plot this way or that way whatever this is that in this problem it might be like this.

So if you like this then if you take here CA0 and then this is CA, so area under this curve you can you can find out as the tbatch, am I right. So here I can show you in this reaction, minus 1 minus 1 minus 2 minus 3, so it is keep on increasing. Now 0.4 is 0.6 then after 0.6, it is again that decreasing. So it is like this, 1 by rA that you know 1 by rA is decreasing that, this is a that means rA increasing that you know initially if you see that the rA is a increasing that as the this is initial substrate concentration and then again it is it is decreasing. So 1 by rA increases. So this is the pattern of the curve that we obtain from this particular if you draw in a simple graph paper we can have this patter of the graph and then what do we essential have to find out this CA0 is here is 1.3 and CA that is 0.3 that the and we shall have to find out the area under this curve.

Now how we can calculate the area? This is like this if you draw this is like this. This is the area of a triangle so you can you know the value of this you multiply this with this you can find out the area and this if you this is the tingle, triangle is half base into altitude. So you can also find out this area and the here also you can find out this and this (())(6:02) that we have in the centimeter graph paper you can find out each root what is the that correspond to what is a time, so you can do that calculation and find out the tbatch.

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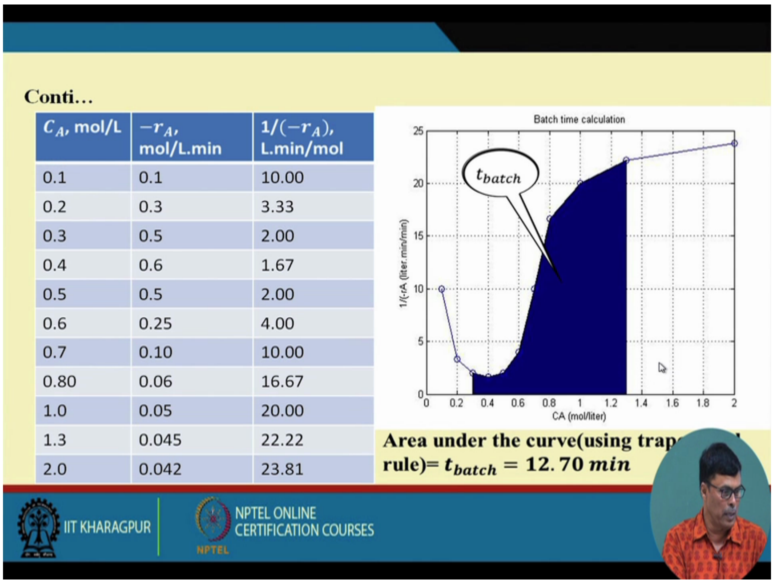

Now we have done this here that 1 minus from rA we can we have calculated 1 by minus rA and we plot here. This is the nature of the plot and you see that this is 1.3 and this is the 0.3. So area under this curve we shall have to find out and if you calculate the area under this curve, it is coming along 12.7 minutes. So you can do by yourself and find it out that how it can be calculated.

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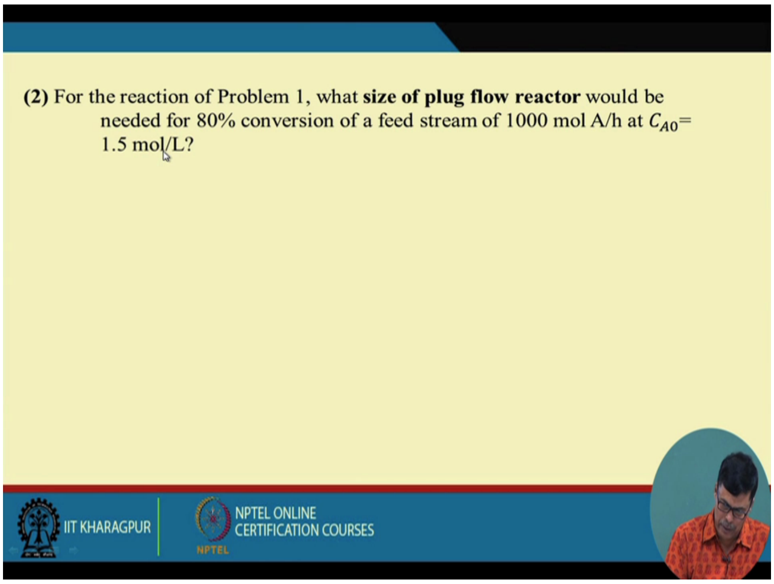

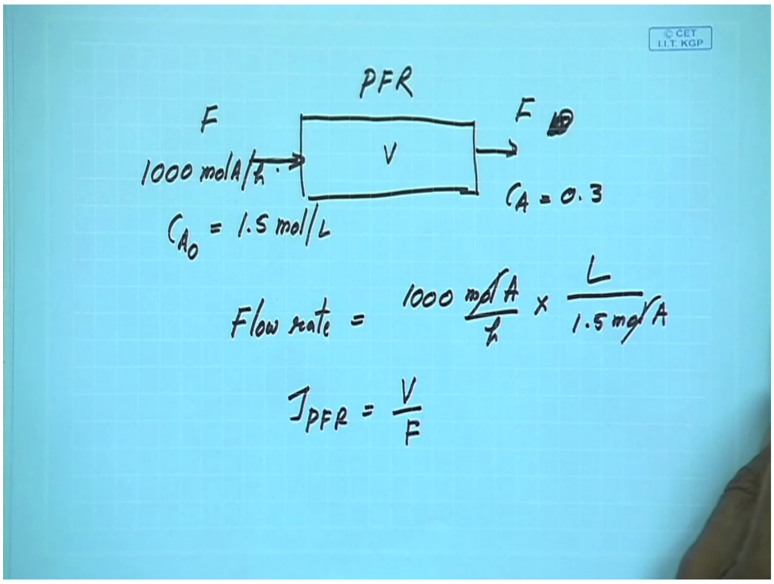

Now next problem that we have for the reaction of problem one what is if the plug flow reactor could be needed for 80 percent a conversion of the feed stream 1000 mols of A per hour CA0 is a 1.5 mol per liter, okay. So what is the this is equal to plug flow reactor. What is the plug nature of the plug flow reactor it this like this. This is the plug flow reactor. Now what is the initial concentration that we have? This is 1000 mol of A per hour and whereas CA0 is equal to 1.5 mol per hour per liter, okay.

Now (())(7:50) than 80 percent conversion that means 20 percent will remaining. So if you multiplied by 0.2 then CA will be equal to 0.3 am I right and here this will be same, this is now this cannot be same 100 mols of A will be converted to be might be. So flow rate will be same, but if you consider here flow rate that you can find out and how we can find out the flow rate? Flow rate you can easily find out that this is the flow rate. How we can find out the flow rate? Flow rate equal to this is 100 mol of A per hour and if you divide by the CA0 is what 1.5 mol A per liter am I right? Mol liter and mol liter will cancel and it will come liter per hour. So you can and this flow rate will be same. This flow rate the input and output flow rate is same and here I told you Tau plug flow reactor is equal to what? Tau for the this is the volume walking volume of the reactor then we can find out v by F this is the Tau plug flow reactor we can find it out.

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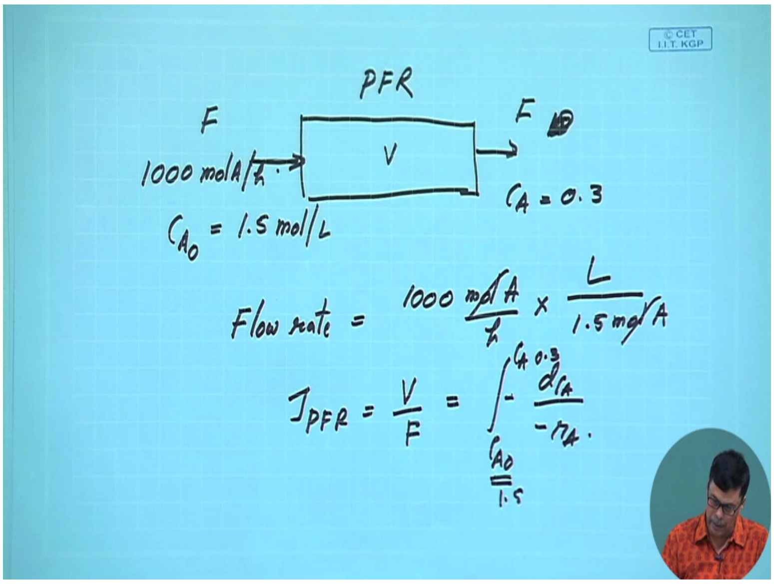

Now here what we have done that we have CA0 is 1.5 mols per liter. Now XA is the 0.8, so CAF is finally is 0.3 as I mentioned and this is the this is mols per hour. So here we converted to minutes if you want to minutes you divide by 60 we will get the minutes. Now in case of Tau plug flow reactor also we have, it is similar to your expression is similar to your batch reactor this is minus dCA by minus rA that is we have here CA0 to CA. So this is 1.5 and this is 0.3 that we have and this is we have we shall have to do the integration like this.

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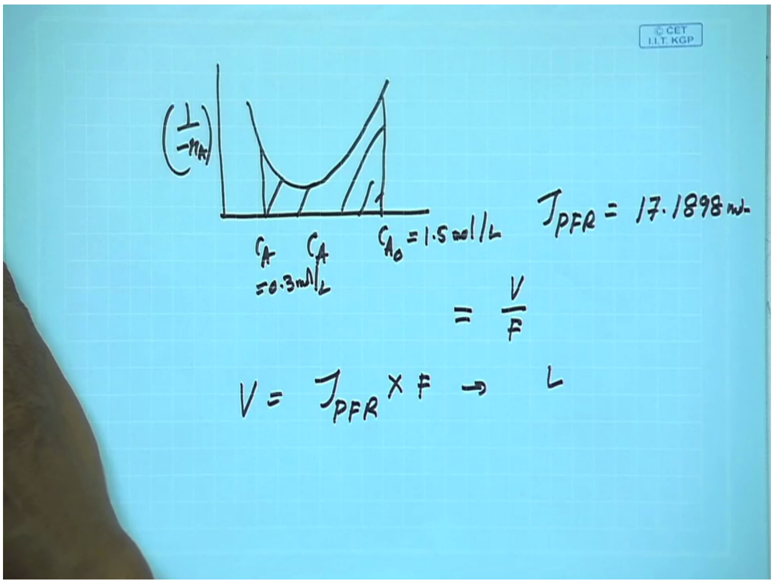
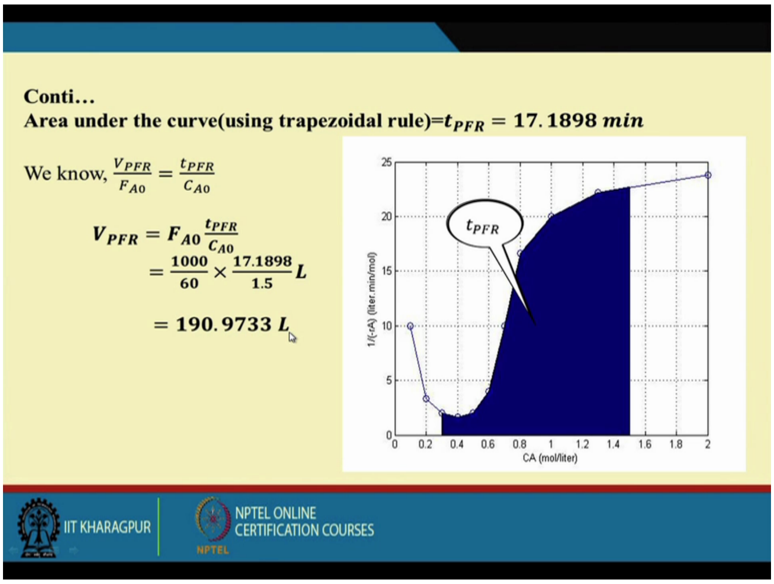




Now and in our previous case that we have already seen, we have the plot like this, one minus rA verses CA am I right. So here we have CA0 and this is suppose CA and this is equal to 1.5 mol per liter and this is 0.3 mol per liter, okay. So area under this curve I can similarly find out and here it has been determine and we say it is found to be the Tau plug flow reactor, this coming about 17.1898 minutes, this is like this.

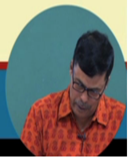
Now we have already seen that this is equal to V by F and F I have already shown you how we can calculate. So if you find out the value of F the V equal to will be Tau plug flow reactor into F, so you can find out in liter this will be the liter. This is exactly what we have found out that Tau plug flow reactor by CA0 if you divide by this, you will get the your volume is coming about 190.9733 liter, (()(12:05) volume of the that plug flow reactor.

(Refer Slide Time: 12:10)

(3) (a) For the reaction of Problem 1, what **size of mixed flow reactor** is needed for 75% conversion of a feed stream of 1000 mol A/h at C_{A0}= 1.2 mol/L?

(b) Repeat part (a) with the modification that the feed rate is doubled, thus 2000 mol A/h at C_{A0}= 1.2 mol/L are to be treated.

(c) Repeat part (a) with the modification that C_{A0}= 2.4 molL; however, 1000 mol A/h are still to be treated down to C_{Af}= 0.3 mol/L.



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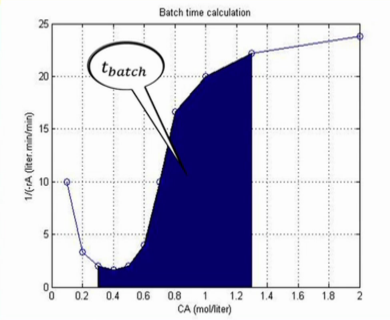
Conti…

C_A, mol/L	$-r_A$, mol/L.min	$1/(-r_A)$, L.min/mol
0.1	0.1	10.00
0.2	0.3	3.33
0.3	0.5	2.00
0.4	0.6	1.67
0.5	0.5	2.00
0.6	0.25	4.00
0.7	0.10	10.00
0.80	0.06	16.67
1.0	0.05	20.00
1.3	0.045	22.22
2.0	0.042	23.81



Area under the curve(using trapezoidal rule)= t_{batch} **= 12.70 min**

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(2) For the reaction of Problem 1, what **size of plug flow reactor** would be needed for 80% conversion of a feed stream of 1000 mol A/h at C_{A0}= 1.5 mol/L?

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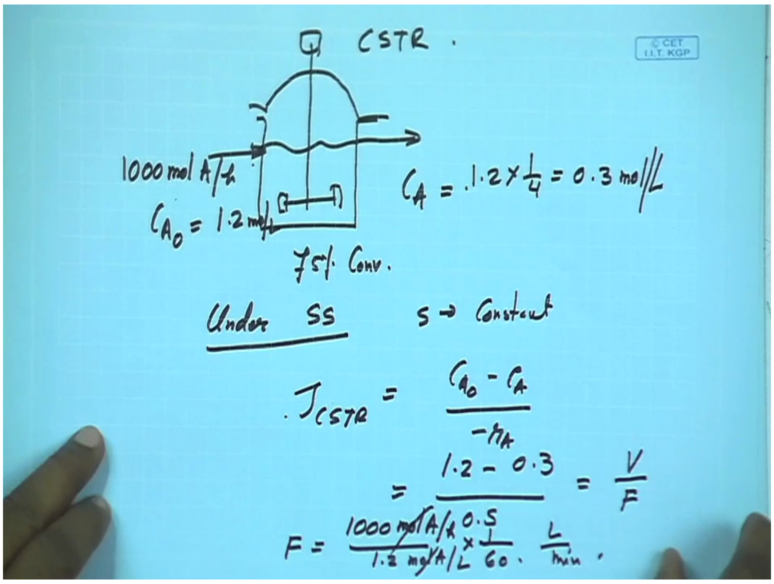

Now second to third (())(12:10) problem is that the same problem now what we are thinking that what will be the size of mixed flow reactor. Mixed flow reactor is similar to your **your** say continuous stirred tank reactor and is needed for 75 percent conversion of the feed stream 1000 mols of A per hour at CA0 1.3 mol per liter. So that we shall the reactor will be like this your continuous stirred tank reactor can be expressed like this. So there will be continuous inflow and continuous out flow, this is CSTR am I right. So here saying that input here we have 1000 mol A per hour and CA0 is 1.2 mol per liter (())(13:22) the CA this is 75 percent conversion. So 75 percent conversion means this will be multiplied by 1 by 4 and this will become that is 1.2 into 1 by 4 then 25 percent will remain that means it is coming about 0.3 mol per liter, okay.

So this is like this, so here the here situation is very simple and under steady state condition, what is the steady state condition, because I told you in a continuous system, there is a it is possible that to attain the steady state how it arrive the steady state condition if you drawn the system for infine period of time a time will come when the substrate concentration in the reactor will be uniform and then and only then the steady state formation will reach and this is possible when rate of accumulation of the substrate is equal to zero and that is the best thing that we have and , so under steady state condition is this constant why it is steady state? How you define the steady state? When the concentration of the different component present in the reaction mixture is remain un alter (())(14:53) with respect to time in different section of the reactor it remain un alter (())(14:58) unchanged with respect to time.

So if S is constant then what will be happen that your rate of reaction is constant then your TauCSTR how we have already seen TauCSTR equal to what CA0 minus CA by minus rA am I right? Now what is CA0? CA0 is 1.2 and what is CA? This is 0.3 and at 0.3 if you look at in the problem 0.3 you have the rate. This is 0.5 mols of a mol per liter per minute. So you can multiply by that 0.5, so you can get the TauCSTR and this is equal to V by F.

Now here this is (the) there I showed you (())(16:01) last that the how you can find out the F. F is equal to I can write 1000 mol of A divided by initial substrate concentration 1.2 mol of A per liter the mol of A cancels this. So this is per hour and per hour which we shall have to converted to per minute that is divide by 60. So you can have liter per minute we can easily calculate liter per minute.

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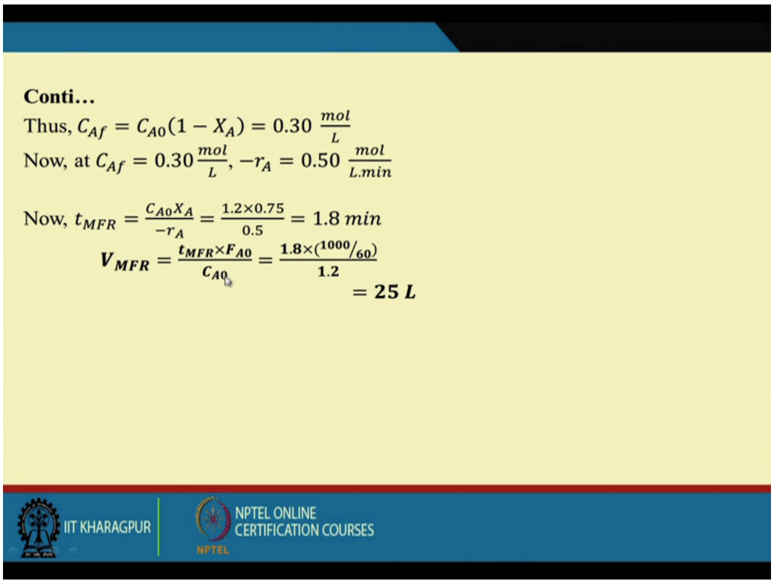

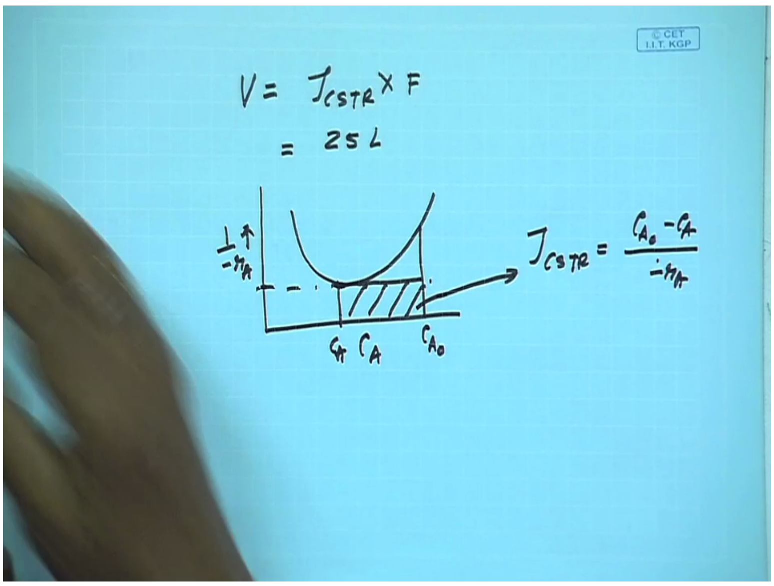

After this calculation then we can find out the volume of the reactor is across TauCSTR into F, so here we did the calculation and we find this is about 25 liters. This is coming about 25 liters. Now here there is a interesting thing, because we can this is how we can through analysis we can determine this volume, but graphically also we can determine the volume of the reactor. How we can do that minus rA and CA when you plot like this, so **so** here may be your CA0 and here might be your CA. So what is happening that what is your equation TauCSTR is equal to CA0 minus CA by minus rA. So here your substrate concentration here you have minus rA value you can easily have and this is the area this area is nothing but equal to TauCSTR. So graphically also you can find out if you want to you can multiply this you can also determine the value of this.

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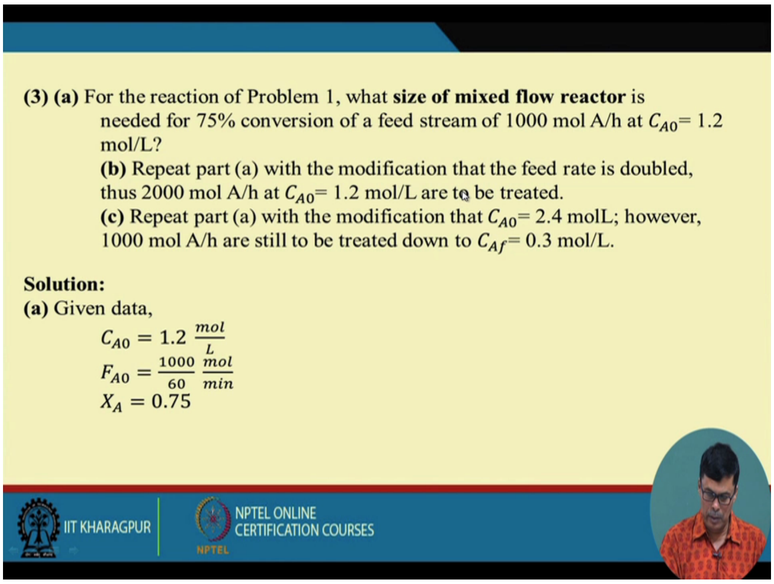

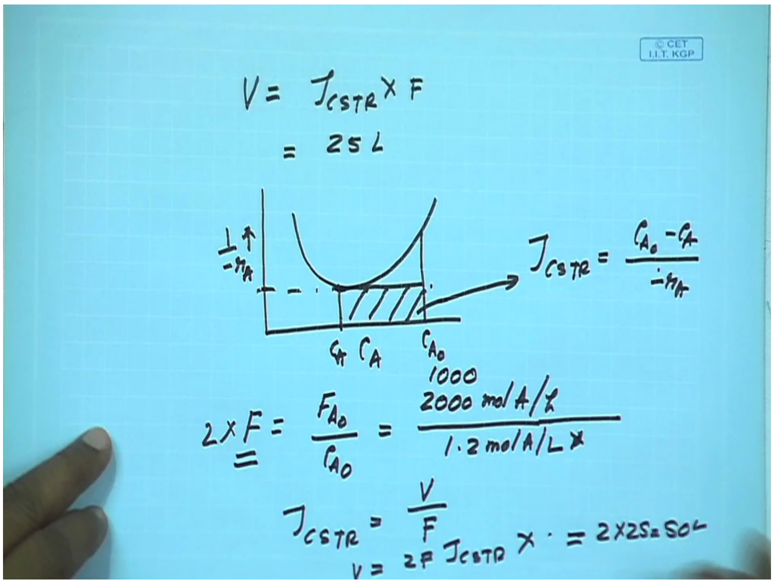

Now next problem is that the repeat part (a) with the modification that feed rate is doubled. This is 200 mols A per hour CA is same to be treated. Now if the feed rate is doubled what will happen? So what si the flow rate I calculated flow rate is a FA0 divide by CA0 am I right. Now FA0 is how much? This is initially was 1000, now it is 2000 mols of A divided by per hour and this is CA0 is about 1.2 mol per mol of A per liter. So you can divide by the 60 to get per minute. So you can easily convert, so what I want you to tell that when you increase this 200 mols basically what is happening, previously it was 1000, now it is 2000 that means flow rate is increased by 2, am I right? Flow rate is increase by 2, so your equation is that you have seen value of TauCSTR same conversion if you have same conversion then this is equal to V by F then V will be what 2F into TauCSTR. So basically that if we double this the substrate concentration the previously it was 25 liter, now it will be 2 into 25 liter that is the 50 liters. So we can easily calculate the volume of that mixed flow reactor you can easily do that.

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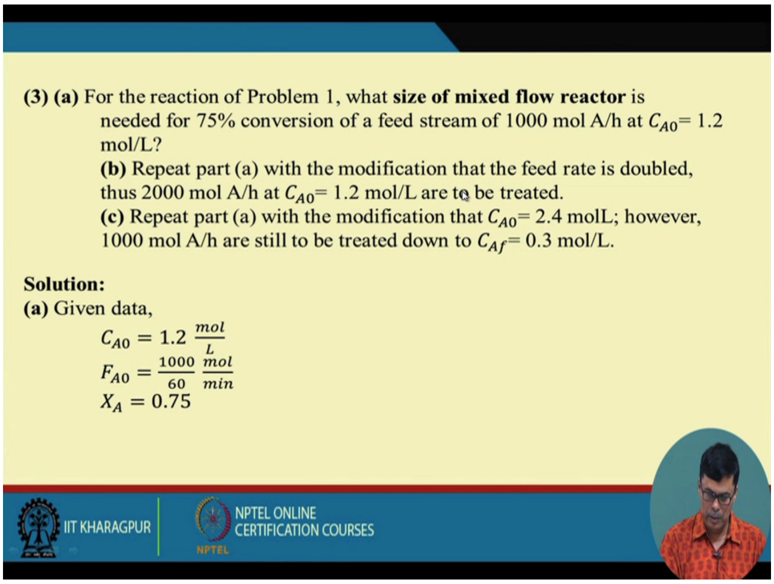

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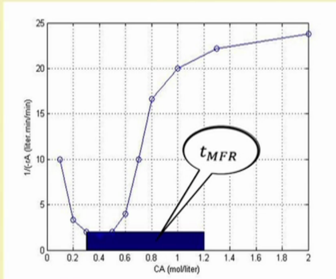
Thus, $C_{Af} = C_{A0}(1 - X_A) = 0.30\ \frac{mol}{L}$

Now, at $C_{Af} = 0.30\frac{mol}{L}$, $-r_A = 0.50\ \frac{mol}{L.min}$

Now, $t_{MFR} = \frac{C_{A0}X_A}{-r_A} = \frac{1.2\times0.75}{0.5} = 1.8\ min$

$$\boldsymbol{V_{MFR}} = \frac{\boldsymbol{t_{MFR}\times F_{A0}}}{\boldsymbol{C_{A0}}} = \frac{\mathbf{1.8\times(^{1000}/_{60})}}{\mathbf{1.2}}$$

$$= \mathbf{25}\ \boldsymbol{L}$$



(b) It is seen that $V_{MFR} \propto F_{A0}$.

Therefore, doubled the feed rate V_{MFR} will be double.

$$\boldsymbol{V_{MFR}} = \mathbf{50}\ \boldsymbol{L}$$

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(c) Given data,

$C_{A0} = 2.40\ \frac{mol}{L}$

$F_{A0} = \frac{1000}{60}\ \frac{mol}{min}$

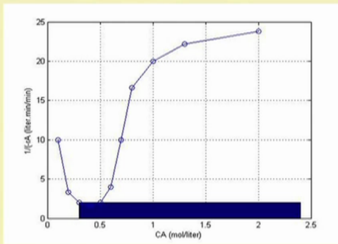
$X_A = 0.75$

Thus, $C_{Af} = 0.30\ \frac{mol}{L}$

Now, at $C_{Af} = 0.30\ \frac{mol}{L}$, $-r_A = 0.50\ \frac{mol}{L.min}$

$X_A = 1 - \frac{C_A}{C_{A0}} = 1 - \frac{0.30}{2.40} = 0.875$

$t_{MFR} = \frac{C_{A0}X_A}{-r_A} = \frac{2.4\times0.875}{0.5} = 4.2\ min$



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(3) (a) For the reaction of Problem 1, what **size of mixed flow reactor** is needed for 75% conversion of a feed stream of 1000 mol A/h at C_{A0}= 1.2 mol/L?

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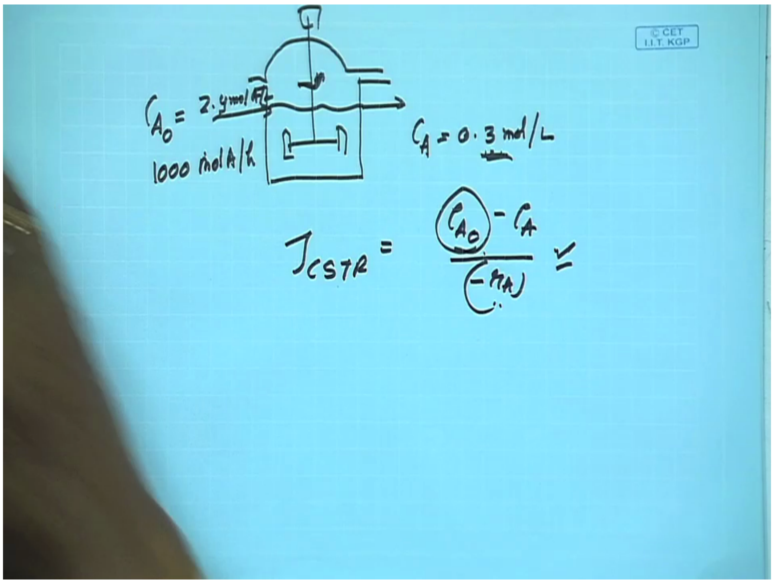

Now next is that we have solve this and we have calculated 0.5 and next problem that we have the repeat part (a) with the modification the CA0. Now what they are saying that here, now here previously CA0 was 1.2 now it is 2.4 mol of A per liter am I right? And here CA is same, they are saying the CA should be same previously it was 75 percent now they are saying no (())(21:15) the whatever convert that is the final concentration remaining same, but here the flow rate is a 1000 mols of A per hour then what will be the size of the mixed flow reactor then how we can calculate then we know this again we can easily do that like you know, in a TauCSTR is equal to what CA0 minus CA minus rA. So this is same, this is 0.3, so this we do not have to change only this has been change. This is 2.4 so you can easily calculate the value of this.

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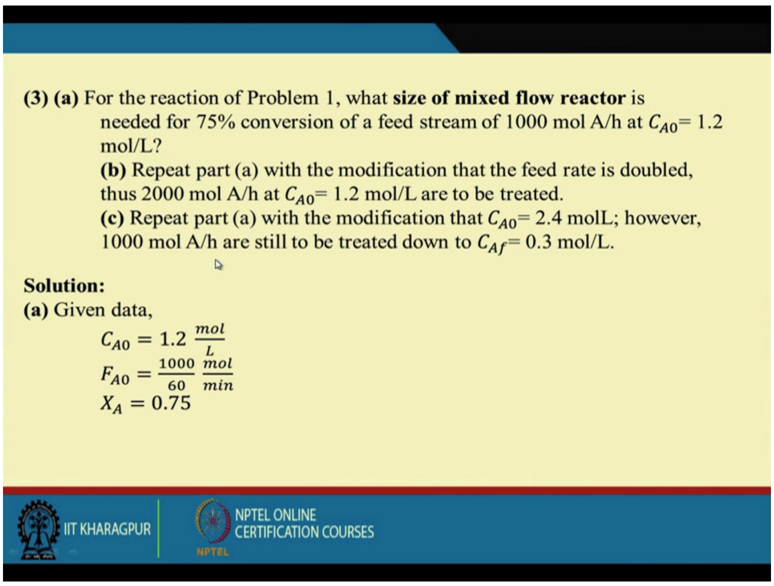

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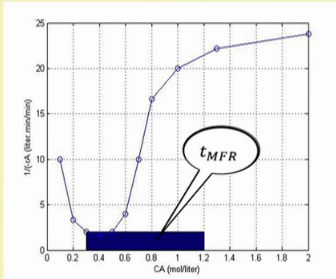
Now, $t_{MFR} = \frac{C_{A0}X_A}{-r_A} = \frac{1.2\times0.75}{0.5} = 1.8\ min$

$$\boldsymbol{V_{MFR}} = \frac{t_{MFR}\times F_{A0}}{C_{A0}} = \frac{1.8\times(1000/60)}{1.2} = \mathbf{25\ L}$$



(b) It is seen that $V_{MFR} \propto F_{A0}$.

Therefore, doubled the feed rate V_{MFR} will be double.

$$\boldsymbol{V_{MFR} = 50\ L}$$

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(c) Given data,

$C_{A0} = 2.40\ \frac{mol}{L}$

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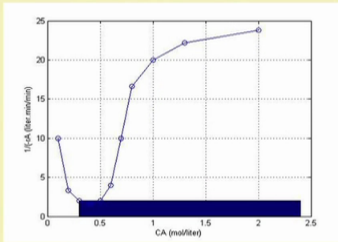

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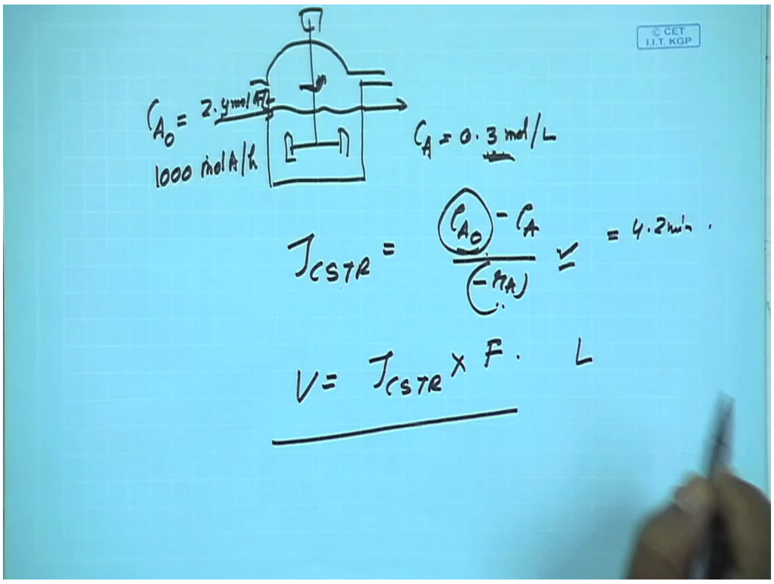

Now I can show you, this value is a coming about 4.2 minutes. Now if you know that then again you can if you want to find out the volume of the reactor for that you can also calculate that what should be the volume of the reactor that also V will be equal to TauCSTR into flow rate, am I right. The flow rate A we have already shown you how to calculate the flow rate, so you can find out and this will come as liter.

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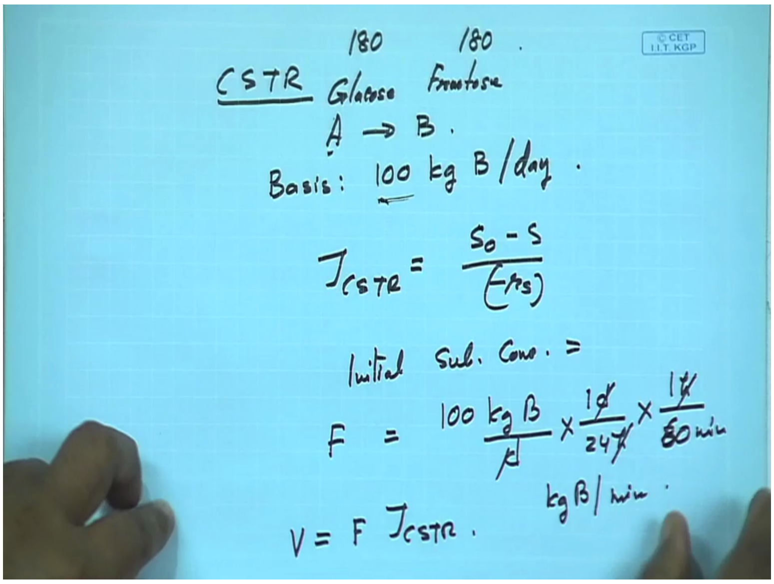

Now here I want to point out couple of things, suppose in case of CSTR we want to convert A into B and we want to produce bases is 100 kg B, let us assume that 100 kg B mols 1 kg of B. So you know the molecular weight of this. Let us assume mole this is glucose to fructose let us assume that. This is glucose converted to fructose. Now why you assume that the both the here is the molecular weight is 180 and here also you have 180 am I right. Now question comes that suppose we want to carry out this kind of reaction how we can determine the volume of the reactor. How we can determine the vole of the reactor? So how we can do that first you have to calculate TauCSTR, TauCSTR how we can calculate. This is S0 minus S minus rS at a particular substrate concentration steady state substrate concentration, you can find out that what is the TauCSTR value you can easily find out and here you know the initial substrate concentration that is glucose concentration you know.

So if you know the initial substrate concentration if you this is suppose this is the amount of this producing per day then flow rate you can easily calculate this is 100 kg B per day. Now one day is equal to what? One day is equal to 24 hours am I right and if you want to convert to minutes 1 hour is equal to what 60 minutes. So this hours cancel day will cancel, so you can easily convert kg per minute if you do that you can flow rate will come as kg B per minute you can easily calculate. Now once you do that then again if you multiplied by this V equal to F into TauCSTR you can do that.

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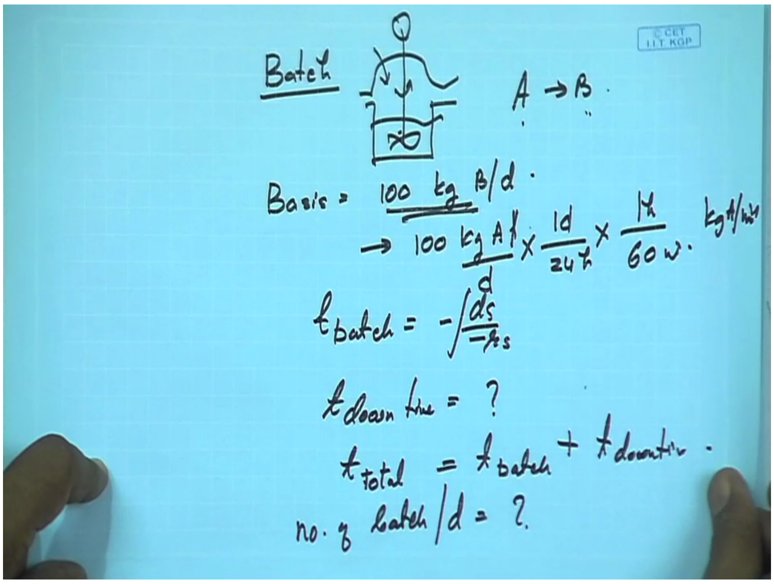

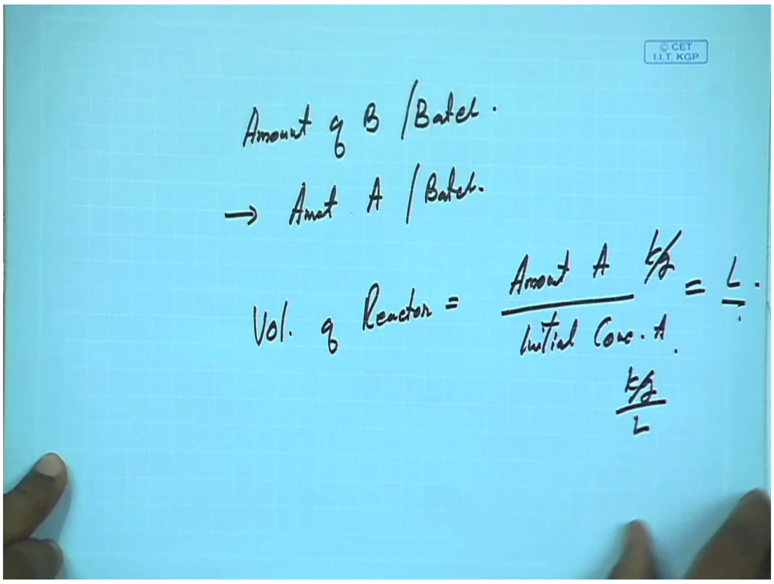

Now question comes what will happen in case of batch process? Now batch process, it is not a continuous process, so it is like this you take the material at a time allow it to react after the material a conversion takes place, here also basis is same 100 kg B per day. So same reaction A to B and we considered this is glucose to fructose, so same 1 gram of substrate give 1 gram of product, so I can write this producer, this required 100 kg of A per day then you can convert into one day equal to 24 hours and 1 hour equal to 60 minutes. So you can easily convert it to kg of substrate required per minutes, so you can easily calculate, okay.

Now tbatch you can find out tbatch equal to same equation that we have minus dS minus rS you can calculate if you here conversion you have to calculate this value but here there is a problem. Here if you do any kind of batch process we shall have to consider the down time tdown time. This down time contains the time required for taking out the product from the after the fermentation is over then cleaning the vessel and then refew (())(27:44) the substrate again in that. So this down time we have to assume or you have to find out. The total time t total will be what? Ttotal equal to tbatch plus tdown time. Why it is required, because I want to find out that how many (())(28:07) number of batches per day we have to calculate and this amount you have to convert not with respect to per day you have to convert with respect to per batch.

Once you have the information that how much product you have to produce per batch then you can find out easily the volume of the reactor. How we can then if divide by then you find out per batch how much substrate is required, because let me show you, suppose you calculate amount of product B per batch. Now if you find out and from that you find out amount of A required per batch. Now volume of the reactor is what? Volume of the reactor amount of A required per batch divided by initial substrate concentration of A. So this is what so this this is the amount is kg and this will be kg per unit volume per liter, so kg will cancel, this will be liter. So you can find out the volume of the batch reactor like this, thank you.