Chemical Engineering.
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Lecture-36.
Multiple Reactions Part V.

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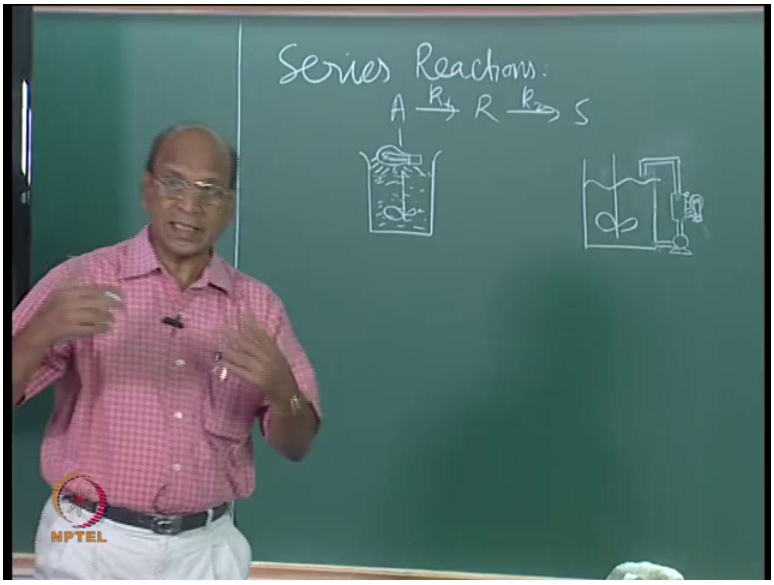

Professor: Good, so we have now, now we will take the series reactions, so series reactions, our famous reactions are A going to R, R going to S, K1, K2. Just to prove that, what kind of contracting is better or series reactions, like exactly what we have done for the parallel reactions. So what it takes is, he takes a beaker, okay and then he puts in this all the, I mean here it is only A, I mean it can be also A plus B also. Okay, let us take to understand easily only A is there, initially at time t equal to 0. And then he imagines that this reaction is happening in the presence of light, okay.

So this solution is irradiated in the presence of you know, by light, so you put say a bulb here, yah that is the bulb, of course, this is the light, here you have to put filament also. Okay, good and of course there is also a stirring, stirrer is moving there. Yah, so this is one setup and another setup also, he just imagines that we have same size beaker, stirring but you will not put light here, but you will take a small amount of solution , this is the pump, then it goes through a small pipe and here there is a glass, very small one. Yah, okay, yah. So here you put the bulb now, yah, this is the bulb where again you have light.

Yah, okay, so the difference is that here, we have a small amount of solution coming and the same intensity is also used, right, so then the solution is exposed to that light. Whereas here the solution is exposed to this light, entire solution is exposed, whereas here it is only small part, okay. So now let us see, hand and here also it is A, here also A at time t equal to 0, right. Yah, you have discussed this in your B tech? Some of you would have discussed, I mean, most of you would not have discussed that. So then what happens here let us see. The reaction is happening in the presence of light, right, so when you switch on the lights come at time t equal to 0 after failing up and after stirring, then what will happen.

Light will go and attack the entire contents, okay, then what is your maximum now at time t equal to 0, which components, let us is there. So then A is exposed, that means A is exposed to the light, okay. And because of this, presence of light, reaction proceeds, right. So let us imagine afterwards you know maybe after 30 seconds, so that means some R would have formed because reaction is going on, the moment you switch on the lights. So after that I have some amount of R and some amount of A but because we are talking about immediately after 30 seconds or 45 seconds, which one will be more, and which one will be less?

A will be more because I think not 100 percent conversion is not occurred there, A is more and then R is less. So that is why still A gets more light because simply these more there, right. So like that you will ever again next time period if you discuss, then imagines, then what happens again is that you will have again slightly more A and less R but R composition is slowly increasing. After some time maybe I think, just values only after 10 minutes probably, you will have more R and less A. Now the light, if R gets more light, right and then A gets less light, this reaction is still going on but this is started reacting to S.

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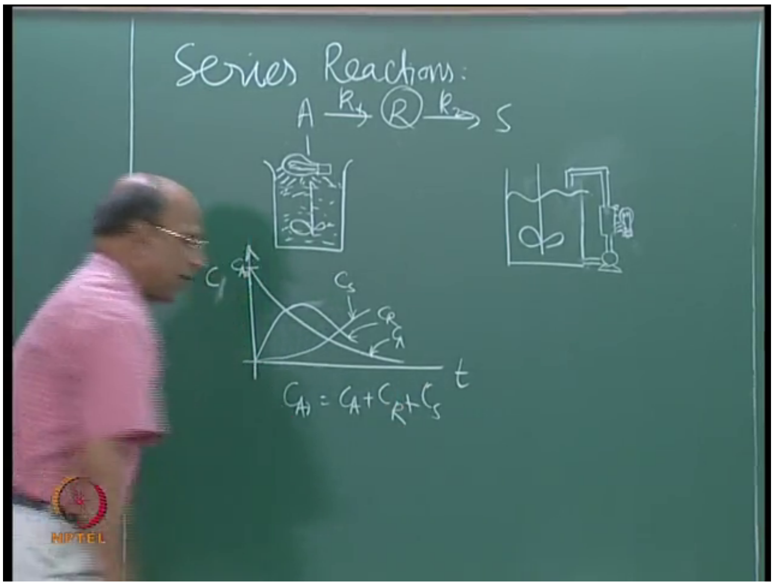

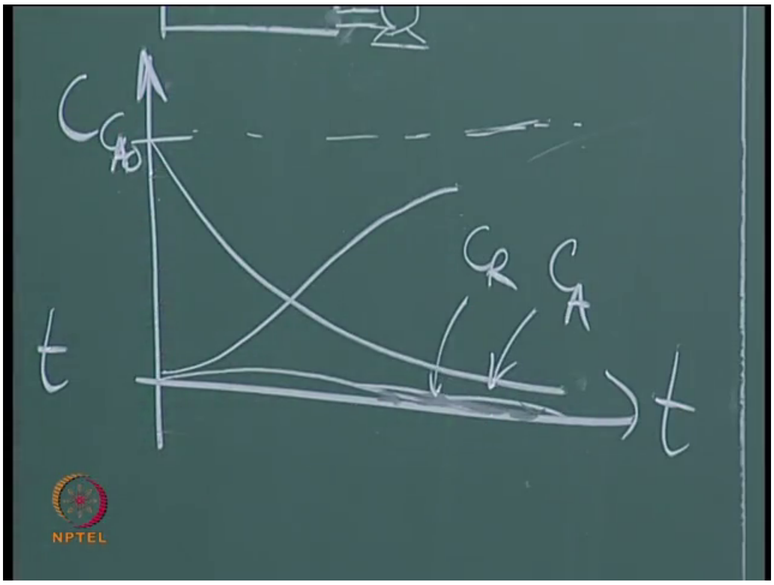

So like that with more and more time when you analyse, finally A will be everything converted, then R also will be converted to S. So you will be left with only S in the system, okay. So that means when I plot this, CA, okay, C versus time, with the time only what you are plotting. Then you have A, this is CA0 decreasing like this, correct no analysis CA and R we know initially to 0, right, then slowly some amount form and then increasing and then increasing. And it goes like this, yah, so afterwards when more light, more light is going to only R and less light to A, then this will start decomposing more and more.

So then it will reach a peak point and then goes down, right. But S will start, this is CR and S will start slowly and then finally it may reach, this is CS. If all A is converted to S, then you will not of course, again you know only you will see this line, all other things will become 0.

That means at the end you know, finally when you allow it for completion. Because it is not reversible reaction, it is only irreversible, so finally you may reach, for long time if you wait only CS. So that means this is the one and our interest here is R, R is the desired product. So now we have to find out what is the time, that is maximum CR you get and beyond that you should stop the reaction, okay.

So this is one way of operating the system and you get this kind of concentration profile. Yah?

Student: (())(7:39).

Professor: Yah R will be decomposed.

Student: (())(7:46).

Professor: No, all 3, at any point of time all 3 must be same, all 3 should satisfy this relation. If I take pure A, this is valid at any point of time, if I take at this point, all 3 concentrations must be this concentration, okay. So that is there, I mean it may not be exactly to scale, so that is why somebody may not get that kind of thing, so but all 3 must be satisfying this condition, CA 0 equal to CA and all that. Okay, good. Now if you go to this setup, now what will happen let us see. It started at the right time t equal to 0 you switched on this and then pump is running pump is running and you switch on this light.

And when you switched on this light, the intensity is same but here amount of liquid is more and here amount of liquid is less. So that means in the presence of highly intensive light, then this will be practically going to completion of the reaction. What is the final completion of the reaction? This only, okay. Yah, so that means there will be small amount of R may be there but essentially it will go to S. And that will come back here and again you are taking out, and when it is coming here, only S is coming inside, right, and then you have again practically more A only, again A will come here when you are recirculating.

And , same amount of A, small amount of A will come, goes here, getting reacted and again S coming here. Okay, nice. So under these conditions, how do I plot this, concentrations, C versus time again. Right, what will happen to CA, this is CA 0, this is decreasing anyway, this is CA and what will be A, sorry, R? R will be, it will be very very small, like this it will be. This may be CR, that means practical you do not see much concentration of that are inside the here, inside this character, okay. Yah, inside this tank. And S will be going on and finally at this point it has to go, yah, maybe beyond this it will go to CA 0 where again all 3 must be equal to 0, right. Okay.

So what is that lesson what you have learned here? This is, this is CS, what is the one, what is that we have done in this case and what is that we have done in this case? Yah, here what we were doing is, we are now just leaving the concentration on its own and just waiting for the reaction to occur in the presence of light anyway. Okay, right, this is one kind of contacting but here what we are trying to do, you are now trying to here, a stream you are mixing with a different composition of A. Correct no. I mean here practically there is no A, everything is converted to R or S but mostly S because intensity is very very high. That means here, 2 different concentrations are mixing, streams of 2 different concentrations are mixing, that means this is not a stream here, this is already there and then you are sending this stream into this with a different concentration.

Whereas here you simply allow the system for the reaction to take place. Okay, so if you want your R as a product, which system is better for that? The 1st one. So that means what you have to do? To maintain this R high, what is the kind of system what you choose? Reactor, now you come to our reactors, which reactor will maintain this kind of condition, which reactor will maintain this kind of condition? This is PFR or another alternative, batch. Either batch or PFR will give you A going to R, R going to S, our R is maximum when compared to a mixed flow reactor where you have some reaction going on already, you have some concentration which is different than the fresh liquid which is entering.

Correct no, the fresh liquid which is entering, that is CA0 and it is mixing with the liquid which is inside the tank, whose concentration is at the outlet concentration of the all the components, it may be S, it may be a R, it may be A. So that is what exactly we will do here, that is why you do not get much R, so do not use mixed flow reactor if you want to get more R. Okay. So this is the wonderful thought experiment that means this is true everywhere. So whenever you have an intermediate, in fact it is not only here, I can also put T. If you want intermediate this and this, you go only for this one, not this one, okay.

And chlorination of benzene is one of the very good examples for this, you know benzene chlorination where you have series-parallel reactions, okay, or only series reactions, benzene, benzene chlorination. Monocloro benzene, dichloro benzene, trichloro benzene, they are not parallel, I think they are series. Series, there is one of the famous examples where lot of information is also there in, industrial information is there in that. Okay, so this is the rule, now let us, let us recall that rules so that you remember that. You have drawn these figures so, both the figures? Very good, yah.

Yah, you can write now just below that, in the 1st beaker, you can write this one as 1st, this as 2nd beaker. In the 1st beaker the contents remain homogenous throughout or changing slowly with time, whereas in the 2nd beaker the reacting fluid is continuously being mixed with fresh fluid, okay, correct no, this is fresh. This is always at CA 0, right. And then you are now bringing another scream with a different concentration with a little bit of R and mostly S, okay, good. So full stop there, in other words we are mixing 2 streams of different compositions, okay, now the general rule you write just below next para.

For reactions in series, the mixing of fluids of different compositions is the key to the formation of intermediate full stop. The maximum possible amount of any and all intermediates is obtained if fluid of different compositions and at different stages of conversion, fluid of different composition and at different stages of conversion are not allowed to mix, that is a rule law, right. I do not know, maybe without understanding you would have just taken down. Right, we just go through once more, for reactions in series, the mixing of fluid of different compositions is the key to the formation of intermediate, okay, how you mix is important there.

The maximum possible amount of any or all intermediates, it need not be only one intermediate, it can be even you know one more. But all these intermediates when you want, okay, the maximum possible amount of any and all intermediates is obtained if fluid of different compositions and at different stages of conversion are not allowed to mix. So just leave it on its own, okay, good. So next para please write. Based on this we can say that batch operation and PF, batch and PF, batch and PF should give you a maximum R because there is no mixing of fluid streams of different compositions.

On the other hand and MFR should not give a high yield of R because a fresh stream of pure A is being mixed continuously within already reacted fluid in the reactor . I think this is clear no? This I do not think you can forget also because you can remember those 2 things and then always remember that for series reactions if the intermediate is one of the desired components, right, then do not mix the streams, just allow, like in batch reactors or in plug flow. In plug flow you are just making them entire and then just you are collecting at the end, you are not interfering anywhere, whereas in mixed flow, you have reaction going on and continuously you are putting fresh, okay, that is stirring at very high speed.

And that means your mixing 2 different compositions which will not give very high intermediate conversions, intermediate concentrations or intermediates, okay, good. So now let us check that you know what we have learned through small diagrams like these. Which contracting pattern will be better, okay. So, shall I write here or… Yah, I think you take this and then (())(17:29). Which contracting pattern of of the following figures, next para you write, examples otherwise, example.

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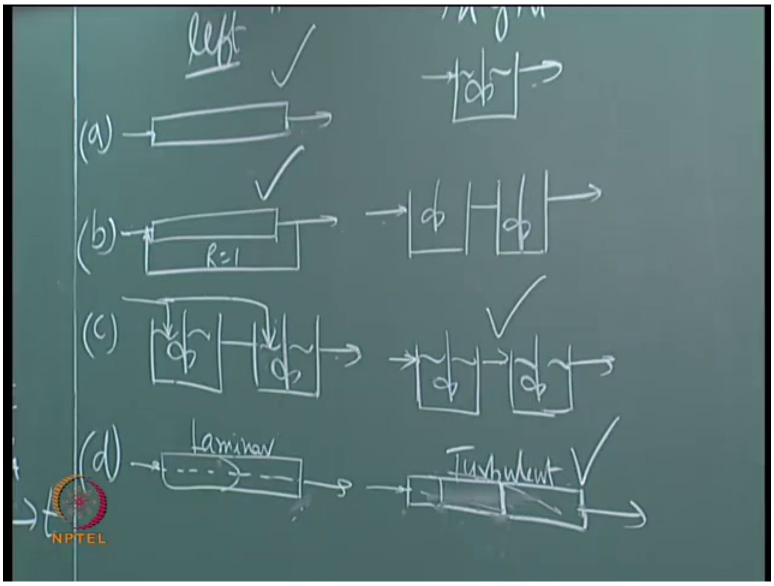

Which contracting pattern of the following figures can give you higher concentration of any intermediate, that is your right left or right because I am going to draw 2 figures on left and right, so that is why. Left, we will have the right. So one contracting pattern is this, that is simple PF, were reactions are these, A going to R, R going to S, maybe T also, okay. So right is, so that is the kind of contracting pattern. Then that means either left-to-right, which one is better? So B is PF, with recycle where R equal to1 and here I have 2 tanks in series, okay.

Yah, another one is C where I have 2 tanks in series, yah but the feed is distributed like this. And in this case, yah, in this case, this is simply like this, good, that means between this and this which is better. So D is, this is a simple pipe but laminar flow and here also I have left side a pipe, that is turbulent fluid inside moving, okay. So now we have to just discuss very simple things only. Which contracting pattern is better to get the intermediate? Like let us say R is our product, what you want, yah, so the 1st one is left is right, left is right, okay. Nike, Nike symbol no tick, yes, okay. This is 1, left is right, so then the 2nd one?

Student: (())(20:32).

Professor: Left is right. You say right is right, why? How many tanks you require for almost plug flow? Yah, so how many you have there? Yah, and of course you can also ask me sir what is the recycle ratio, okay, that is 0 to infinity, right. But what we feel is, R is, R equal to one is near to plug flow, then this one near to plug flow, yah. When compared this one near plug flow, so this one, again left is right, okay. What about this one?

Student: (())(21:16).

Professor: Now, right is right, correct no, now observe and tell me why right is right.

Student: Left is right.

Professor: Why left is right?

Student: Because we are getting C0.

Professor: What is our rule?

Student: Maximise R.

Professor: Maximise…

Student: Intermediate.

Professor: So maximise R is not the rule, what is the rule?

Student: (())(21:42).

Professor: Oh, you remember only old things. Which one is…?

Student: We should not allow the intermediates to mix.

Professor: Yah. But is it happening here or is it happening here? The intermediates, we should not allow them, if it is not, I think different streams of different concentrations should not get mixed, yah.

Student: (())(22:15).

Professor: Here, here again we are mixing fresh one with some other concentration, right, and here the fresh one with some other concentration, okay. So that is why this is not right but right is right, okay, good. What Simi, you are Simi no? I think between you again and confusing, I think she is Neetu, right? You are Neetu okay, ask me, you are asking what? Tell me? Okay, anyway, so next one?

Student: (())(22:57).

Professor: Right is right, why right is right?

Student: Because turbulent flow… (())(23:02).

Professor: Left is right Dinesh, what is your name? (())(23:10) means beginning, so beginning in Narayana is telling you you know… You say left is right. You say right is right or left is right?

Student: Right is right.

Professor: Pooja, Centre is right? Why unnecessarily all the problems, okay, somewhere in the middle. Okay, that is why I think this Buddhism, Buddhism, Gautam Buddha always told that always better take a centre path, Middle Path, middle path is always safer. So Pooja… Right is right. I am going to ask both of you, why, Ajnarayana why do you say left is right?

Student: Because there is mixing of…

Professor: Confusion has still not gone. Yah, yah that confusion has still not gone. The turbulence in plug flow when you say, you are talking about velocity profile which is not the turbulence you imagine in the mix flow reactor. That is what you remember, now I am afraid to say Kayes, this is a problem you look, I do not know whether I have told you this also, this also, once you are aware of something, it is really problem. This turbulent, I think Ajnarayana, that is one that is sometime back also, when we were discussing PFR, some people came and asked with merit, he came and asked me, okay.

So when you are talking about the pipe flow and then turbulence, what kind of turbulence you are imagining there? It is not the turbulence where this molecule is coming and mixing here, right no, in the actual pipe flow when you say turbulent pipe, turbulent flow, what are the Reynolds number you are talking 1st of all? Yah, above 10 to the power 5 and all that. They are very large values and what kind of, you know the diagram that you draw there to show the turbulence, you also draw them, many times turbulence means what you draw. You draw only pole like that, correct no.

It is not, you do not draw like this, like this, like this, right. So this will give me, this turbulence will give me almost flat velocity profile, okay. I mean this is very good, actually in fact I do not know, you are not appreciating any, I told you to appreciate myself, only for this reason I have drawn this example. It is there in (())(25:54) book. Otherwise this is very simple one, I do not have to discuss that much. I expected that, thanks for you know fulfilling my expectation, okay. I thought that you know this will happen, some people still would may be thinking that laminar may be better because there is no mixing here, okay.

But there is residence time distribution, when I have flat velocity profile here, what is the residence time distribution, 0. Whereas here I have the laminar profile where the molecule which is sitting on top of it will come much faster and molecules which are coming near the walls, they come late. We will also have that relationship, average velocity and then maximum velocity. Maximum velocity is, yah, while the average velocity or otherwise half of the average velocity is half of the maximum velocity, right.

So that means if I take 10 minutes is the main residence time, right, so I will have molecules coming out 5 minutes afterwards. Till then you do not get anything, right, so that is why this one, turbulent means this is the one what you have to imagine in your pipe flow, where the turbulence is not from that end to this end, okay. The molecules are only going like this and then moving forward and if you draw the velocity profile, almost it is like a flat velocity profile but depending on the velocity you will see some slight bending near the walls.

And in our imagination of plugged flow, we are taking that also straight, okay. That is why this is more near to plug flow, this one is more near to plug flow, that is why again right is right, okay. So we have 2 lefts right and 2 rights right, 2-2. So this is a very simple scheme what we have and then I think this is a very nice simple things what we have. Now I think it is your problem now, that means I am just going to write the equations, you have to derive them. Some of them you would have already done in your B tech because for simple schemes like A going to R, no, this one, A going to R, R going to S, you have already derived.

Did you not derive what is CR Max, corresponding to that what is T makes, these are the favourite problems for Gate examinations and even your CR examinations, okay. So that is what again I am going to repeat but later I think unless you work again, one for at least you cannot solve in the examination, okay, good. So that is what what we are going to right now.

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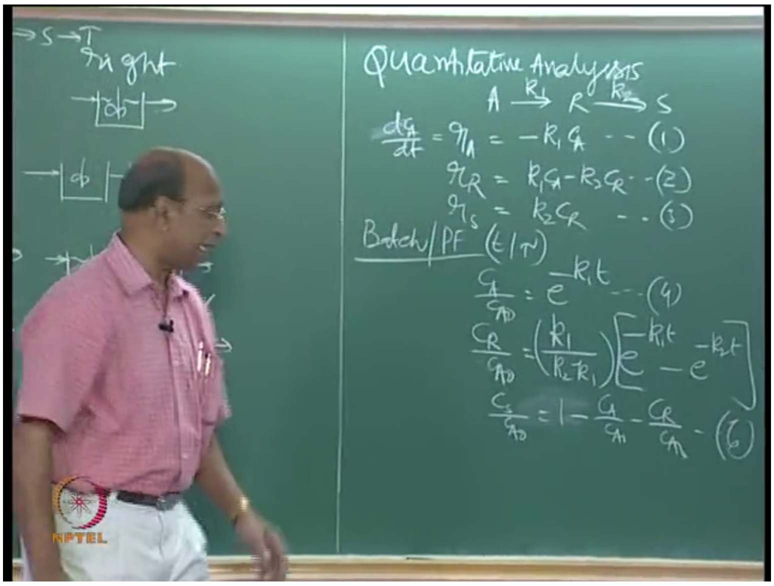

This is qualitative analysis, qualitatively we have discussed what kind of reactor will give the best product, right. Okay, now quantitatively, quantitative, quantitative analysis. Okay, so we have again same reaction K1, K2, yah. 1st we have to write the rate expressions, so rA, how do I write here? I can also write minus rA, otherwise rA equal to, to maintain the uniformity, some books write K1 CA, this is equation 1, okay, rR, yah, Puja K1 C1, K2, CR, that is equation 2. And RS, K2 CR, okay, this is equation 3. So now either batch or plug flow, because it is constant density system, batch or plug flow will give me the same equation but you have to replace time by Tao, that is all.

Okay, please write that, time by Tao tr Tao, okay, good. Now I think this is very simple to solve because this is nothing but DCA by, this is now minus plus only because minus I put there. So the 1st one will be CA by CA 0 equal to e power minus K1 T or K1 Tao if it is batch, if it is plug flow, okay. Good. So then CR by CA 0, but this is difficult for you, you have to do that, I do not know you solve any problem using integrating factors and all that. How many maths course you had in B tech? Differential equation in 4? Differential equation is one, you also had partial differential equation is?

Student: Yes.

Professor: Okay, I think that knowledge is arising required here. So here you will have K1, K2 minus K1, e power minus K1 t minus e power minus K2 t, this bracket is there, right. Yah, so this is 4, this is 5 and of course CS will be, yah, CA 0 minus, yah, CA, otherwise I have to write… Yah, yah, yah, either that I think someone told 1, at 1 you will get if I divide by CA 0, this is 1 minus CA by CA 0 minus CR by CA 0, okay, simply can substitute these 2 and then you get this is the 6th equation. Because now our interest is to find out CR and CR has the maxima problem, but CA does not have that problem, it will go to highest if you just leave it.

There is no optimisation there, optimisation comes only for this, but I have to find out which T and which CR, maximum, okay. So that is why we have to now differentiate that equation 5, I think again I am requesting you, you have to practice CR by CT, yah, that is right, equation is not valid for K1 equal to K2, that is very good. This is only for K1 not equal to K2, right. But you know this equation is also valid if you take the limits K1, K2, you know the derivation you take a mother is a mathematical derivation also for that. But safest is K1 equal to K to equal to some K's and then solve the differential equation, you will get the simplest form, okay.

By the way that is one of my favourite problems in the examination. Already gave up, assignment already gave up, yah, you see, either assignment or examination, so I think you know, only mathematics. Thank you for reminding, so this may have to differentiate. So once we differentiate this, what you get CR by C, okay, I will write here. CR by CA 0 max, Max I think CR Max I will write equal to, yah. Some of you may be remembering this, K1 K2, K2 by, to the power of K2 by K2 minus K1, this is to the power, please remember.

So this is again not valid for, yah, so this is equation number 7 and corresponding to this T max, corresponding to this T max is, yah, very good, that is a log K1 or K2 by K 1 divided by K2 minus K1, so this is equation number 8. Yah, yah if you want you can arrange and the other way also. Okay, so these are the think there and the concentration profiles and all that it will be similar to this only, those concentration profiles. So that is why whenever you have the maximum problem, then you have to find out through differentiation what will be the corresponding value, okay, good. Now we will write the same thing for mixed flow, I think mixed flow is a very nice guy, it will not trouble you that much.

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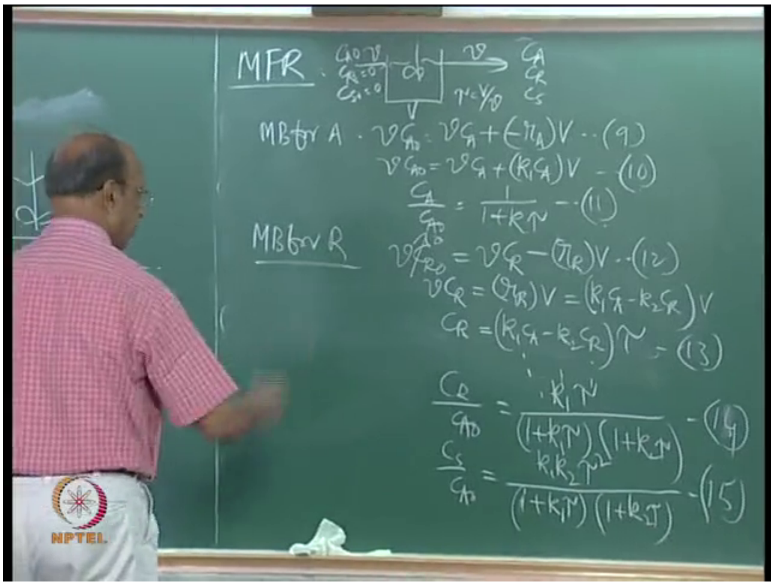

MFR, yah, okay, MFR we can write you know, like the middle balance like you have written earlier. For the Z1 we have written, here also we can write the middle balance, so here again we take normally CA 0 only, CR not equal to 0, CS not equal to 0, here I have CA, CR, CS and volumetric flow rate V, volumetric flow rate V, this is V and we can also write of course in terms of FNR and all that. Okay, for A material balance, yah, again I will write so that you know it will be better for you, VCA 0 equal to VCA plus minus RK into V, why this minus rA can be written as, in this case, K1, yah, K1 C into V.

So from this equation 8, 9, 10, so then you can show this as CA A I C0 equal to1 by 1+ K Tao, where Tao equal to volume by volumetric flow rate. So this is 1, similarly I think, okay, let me write for R. M B for R, so we know this is 0 entry, VC R0 which is 0 equal to V CR minus rR into V, so this is equation number 12. And if you substitute for this rR for this one, okay, and CAlso you will get there, yah, this is VCR equal to rR into V, okay. rR also equal to, rR if I substitute in this equation, this is K1 CA into K2 CR into V or CR equal to K1 CK minus K2 CR Tao. So this is equation 13, yah.

So I can write of course, I am not giving all the steps, the final steps, CR by CA 0,, K1 Tao by 1+ K1 Tao into 1+ K2 now, yah this is equation, this is 13, 14. Again CS by CA 0 also we can write, let me write this time equation K1 K2 Tao Square, whole thing divided by 1+ K1 Tao, 1+ K2 Tao, yah. So this is 15. We have now other problem like, this one maximisation, right. These are the standard nice beautiful problems, so this, I have to get now CR Max, let me remove this. Some of you may be remembering also this one, yah.

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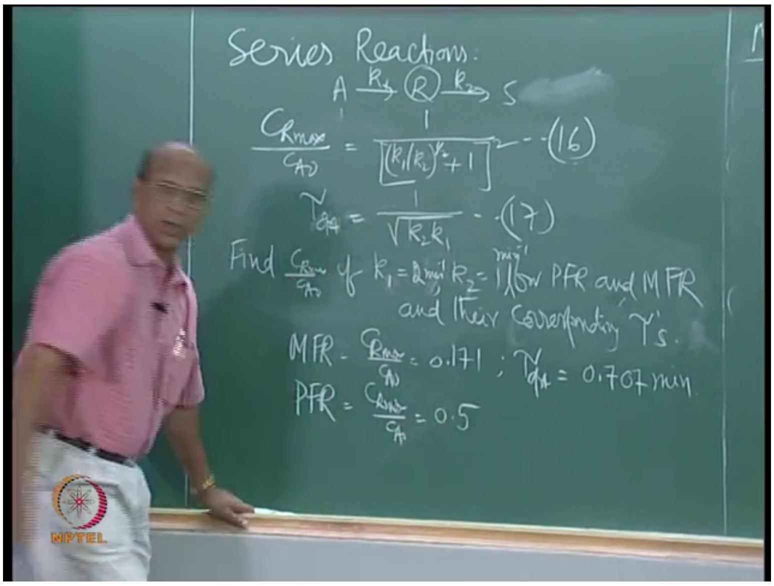


Series Reactions:

$A \xrightarrow{k_1} \textcircled{R} \xrightarrow{k_2} S$

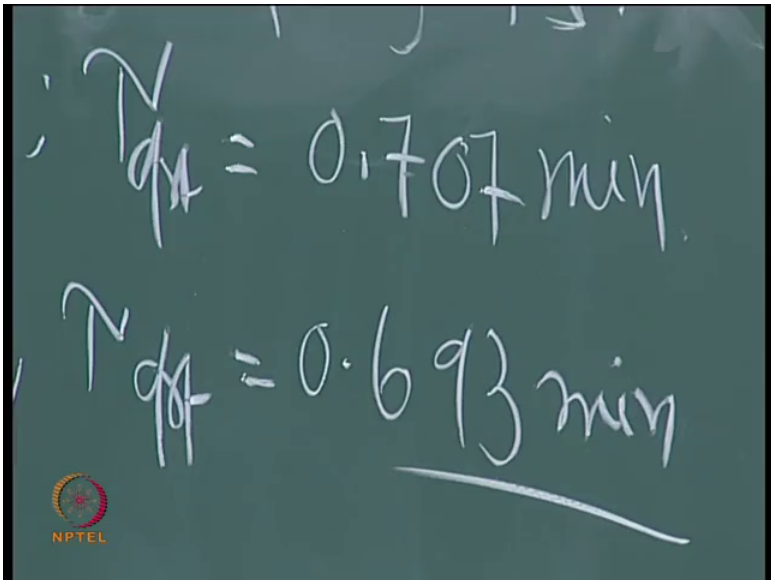
$\frac{C_{Rmax}}{C_{A0}} = \frac{1}{[(k_1/k_2)^{1/2}+1]^2}$ --- (16)

$\tau_{opt} = \frac{1}{\sqrt{k_2 k_1}}$ --- (17)

Find $\frac{C_{Rmax}}{C_{A0}}$ if $k_1 = 2\ min^{-1}$, $k_2 = 1\ min^{-1}$ for PFR and MFR and their corresponding τ's.

MFR - $\frac{C_{Rmax}}{C_{A0}} = 0.171$; $\tau_{opt} = 0.707$ min

PFR = $\frac{C_{Rmax}}{C_{A0}} = 0.5$



; $\tau_{opt} = 0.707$ min

; $\tau_{opt} = 0.693$ min

Nice equations, CR Max by CA 0 equal to1 by K1 by K2, this square, this is equation number 16, corresponding Tao Max, no, Tao optimum VC, not Max there. This is Max, this is optimum, K2 K1 square root, so this is equation 17. Okay. So I think you have come with calculators no? Can you tell me what is the PFR maximum and CSTR maximum, that CR Max in PFR? If I have K2 equal to1 and K1 equal to 2, find CR Max or CR Max by CA0 if K1 or K1 K2, for PFR and MFR, under corresponding Taos, corresponding Tao, corresponding Taos, okay, good. So this is the one, yah, what will be the value? This one is straightforward, this is square root of 2, 1 square root of 2. So 1st I write MFR which is easy, yah, what is CR Max by CA 0? 0.171, correct? 0.171.

Student: 0.171.

Professor: And Tao Max? Tao optimum, not Max? 0.70, 0.707, yah. What are the units, units we have not known, so it is better that I give here units. This is minutes inverse or… Seconds inverse or minutes inverse? So this is let me say 2 seconds inverse or minutes inverse? This is also minutes inverse, so this is minutes. So what is for PFR?

Student: 0.5…

Professor: PFR CR Max by CA 0 equal to 0.5, correct. And Tao?

Student: 0.693.

Professor: 0.693, excellent. This is again just to give an idea that you know when you will have this kind of thing, PFR will give you more yield, CR Max and also, time also is less here, time also is less here, okay, good. So the next one is series-parallel, I will just touch and then, we have also discussed now series-parallel, not much, I think I will not give you much work for series-pile because it is more mathematical but the only thing is that you have to go through the equations, okay. Yah, that is one and afterwards we will discuss a little bit about NB and (())(44:51).

I will give actual references, if someone is interested, started liking reaction engineering, they have to go to original papers and then see. Okay, but I can give derivations in the examination also about this simple derivations, like find out CR by CA 0 and even in then (())(45:09) in some simple cases, okay, good. So this is the one I think again this will prove our rules where we should not mix seems all that. Now when I told you that the concept part is over, right. So now it is only hard work parts, sweating. The thought experiments have gone, so now you have to go to laboratory and then work, so that is why you have to go home and then start deriving all these equations. So that is the hard work part, okay.

By the way how many hours you are spending on CR Everyday? 0. Every 2 hours? Every day 2 hours is excellent if you are able to do. If you are not spending at least (())(45:59) okay. I think he stretches the clock and goes from 24 to 27. Okay. See discipline wise, Everyday 2 hours, 2 hours if you do, I think you are doing wonderfully well. You will do also in the examination. Rahul?

Student: PFR is 0.25. 0.25. 0.25.

Professor: 0.25? I do not have answers, I am just giving… PFR he says 0.25.

Student: (())(46:38).

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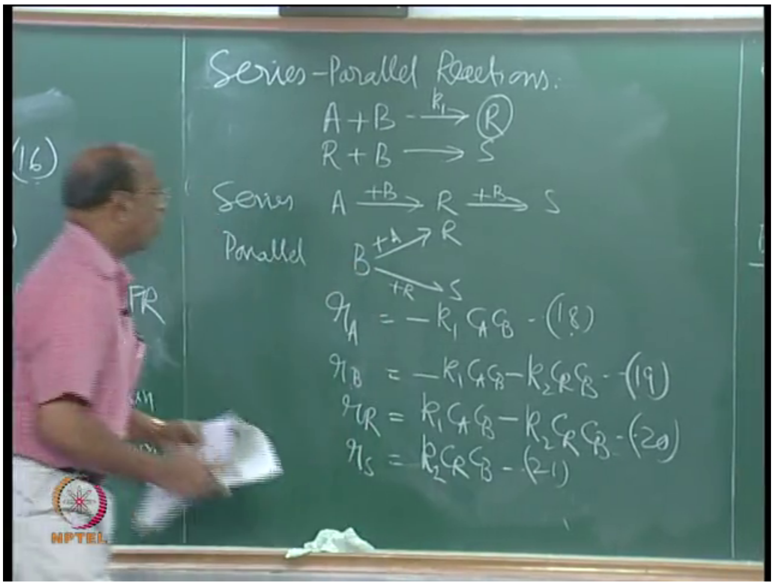

Professor: K1 is 2 and K2 is 1. Check Rahul, otherwise they will come and hit you. Please check that also. So now we have series-parallel reactions. And normal scheme what we have is A plus B going to R, R plus B going to S, okay and this also can be represented in terms of series and parallel. How do I write series, A going to R, R going to S, here I have plus B, plus B. In parallel scheme, okay. See here surprising thing is, I think there is another thought experiment, I think we do not discuss that but only we believe that you know the experiment are right and then see, whatever rules we have applied for parallel and series, there equally applied to even series and parallel reactions.

What is the rule for parallel? If I have a desired reaction with a higher-order, it should have higher concentration, maintain high concentration. And in the case of this series you have to now say that not mix the reactants but just allow them to react on their own, okay. So the 2 rules are again applied for what it is not that easy no, our mind I told you know sometimes, something I have thrown some then chalk pieces and argue how many? So beyond that our mind may not accept, so that is why what you have to do here is everytime a problem is given, just to solve the problem.

That means you have to mathematically write all the equations and then get the solution, if it is CR by CA 0 or if it is by CS by CA 0, okay. Normally this is the desired product, normally, this is what is our convention, okay. Why, you have headache? Under tension, okay, yah. So this is the one and the will try to write the equation 1st for this one. That means again you know some students may not be knowing also how to write rA, rR, rB and all that, okay. So that is why we list out all the reactions, I think when we next do Denbigh reactions, there definitely you will have a lot of possibilities, all the reactions at least, list out all the reactions and then we will take whatever is possible to write the equations.

But I think again the plug flow and batch, you always go to integral expression. You to go to, you have to integrate them, okay. But if you go to mix flow reactors, then there is no integration, correspondingly you have to separate what is minus rR, rR RS, or minus rA, minus rB and then try to get the corresponding concentration. Right, so the overall picture is that, depending on which reactor you are talking, you have the equations, that is why I told you you do not have to learn anything new because the same design expression is only valid here.

We have also for parallel elections what we did, right. And even just now, even these things also, we remove that, yah, mixed flow when you are writing equations for A going to R, R going to let as also, the same design expression. So as far as design is concerned, that is why I told you it is very very easy to remember contacting in the diagram. It is a long time I have drawn that diagram, I think sometimes I have to draw again, otherwise you may forget. Okay, so that is where actual part is, difficult part is only reaction.

You can also see now, particularly when you have multiple reactions, it is a challenge, how do you get all, you know these rates like, let me draw that and then you will see, how do you get rR, rS, rA, rB and all this, did not that easy to get all the constants, that is the real challenge, okay. So now when writing the rate equations R a, I am adding only, everything R a, rB, like that, so that minus also will go this side. D CA by DT if it is a batch reactor equal to K1 minus, I think, maybe I will remove this, we will write generally question. K1, can you tell me minus rA?

K1 CA, CB and fortunately we are not taking any reversible reaction. If you take reversible reaction, Mar Gaya, okay. Again I think, the other them, that will come and integration will be there all that. Okay, good, so continuation, where is the 17-18? So rR, known rB, rB equal to, 1st it is participating here, yah, minus K1 CA CB, minus K2 CR CB, this is equation 19, excellent. Now rR, yah, K1 it is forming, K1 CA CB and again it is, excellent, CR CB, so this is 20. Then RS, RS is a nice guy at the end, it is like a last brother or last sister, least affected for many things, correct no?

The smallest guy in the house weather sister or brother, you will leave them, they are on their own most of the time. So RS is like that, very nice, you what is RS? K2 CR, CB, okay, this is equation 21, yah, K2, okay. So this is definitely complicated when compared over series alone or parallel, from here onwards you have to really think how to solve the problem. There are no simple rules of integration or simple rules of differentiation, okay. Why I am saying that is, then you know sometimes, yah you have to get the relationship between, okay, one example I will tell you.

I have now here CA, CB, CR, 3 are there, right. But I have to convert this one into only one, on components, either CB, okay, mostly CB only. So then only I can solve that. That means you have to now find out what is the relationship between CA and CB and what is the relationship between CR and CB. So that is what is the difficult part there. So to get that part, what have to do sometimes is that you have to manage with these reactions to get, okay, I think I will remove this.

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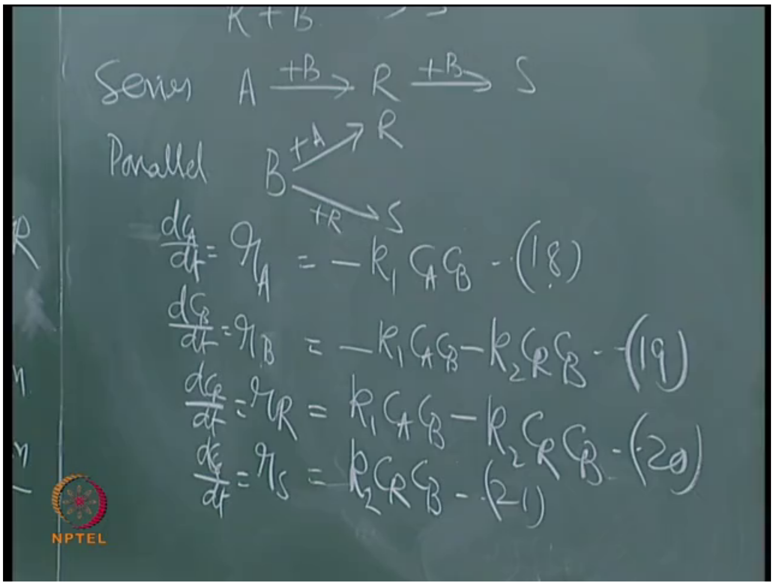


$R + B$

Series $A \xrightarrow{+B} R \xrightarrow{+B} S$

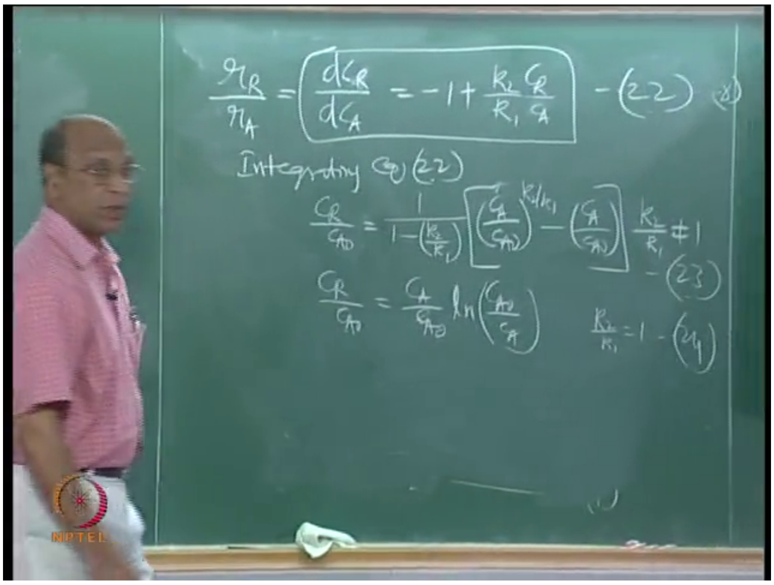
Parallel $B \xrightarrow{+A} R$, $B \xrightarrow{+R} S$

$$\frac{dC_A}{dt} = r_A = -k_1 C_A C_B \quad (18)$$

$$\frac{dC_B}{dt} = r_B = -k_1 C_A C_B - k_2 C_R C_B \quad (19)$$

$$\frac{dC_R}{dt} = r_R = k_1 C_A C_B - k_2 C_R C_B \quad (20)$$

$$\frac{dC_S}{dt} = r_S = k_2 C_R C_B \quad (21)$$



So we have to manage let something like this, like only remove the time, okay, remove the time variable for example. That means, okay, this I also told you, if it is a batch system when you are taking, this is nothing but minus DCA by, DCA by DT. This is D CB by DT, this is DC R by DT, this is DC S by DT. Okay, good. Our relation is, our idea is to get somehow the relationship between, you know few expressions. Like to eliminate one of them, like for example CA, CB and if I want to express all this in terms of only C, CB alone, like that here, it is only in terms of CR alone.

So for that kind of thing you have to like rR by rA. What is the relationship? That means I have here DCR by DCA, negative we have brought this, okay. Yah, so this equal to tell me. Pooja is very good I say, I think without writing, all thought experiments, good, good, Pooja, like that only you have to do. If you are able to imagine everything in the mind, nothing better than that. Minus1 plus CR by CB, okay, yah. So now to get a relationship between CA and CR, I have to differentiate, I have to integrate this. Correct no, I have to somehow find out CR come separately, CA term separately and then I have to integrate, right.

This is a differential equation, as far as possible, it need not be always DCA by DT, right. So that is why here DCR by DCA, this is also a variable for me, this is a variable in terms of CR I have to find out. So that will give me the relationship between CA and CB. Right, so now on relationship I will give, that means this differential equation has to be solved. Why I am telling all this, probably now you know you stopped, you stopped listening to me sometime after some time, now again. That is why, maybe another 15-20 minutes, I think, Denbigh reactions also we will finish, okay, yah.

So we are doing all that because finally we have to get the relationship between this concentration like in this, in this also we have CR and CB and CA. So I have to convert this and that equation into 1 concentration possible, okay. And this also similarly, so that is why you have to look at all these equations and then see which one will give you that kind of relationship. Like if you solve this, if you solve this, what we will get is, CR by CA 0 equal to, integrating, what is the number, 22, okay, let me also write here, integrating equation 22, yah. What you get is CR by CA0 equal to 1 by 1 minus K2 by K1, CA by CA 0 K2 by K1 minus CA by CA 0 which is where, which is not valid, okay, which is only valid for K2 by K1 not equal to1.

Okay, so this is equation 23 and CR by CA 0 equal to CA by CA0, yah, so mistake, CA 0 by CA alone, yah. So this is valid only for K2 by K1 equal to1. So this is equation 24. You see, this give me the relationship between CR and CA, is K2 is not equal to K1, this one is K2 is not equal to K1 and this one is K2 equal to K1. Now it is too much mathematics, that is all, but again I tell you too much, what too much mathematics, they are not really too much mathematics, it is only mostly first-order differential equation. So you have various techniques to solve this, you have integrating, what is that, integrating factor, yah, what are the other methods? That is all will be known, nothing else. Yah?

Student: Homogenous.

Professor: Not partial, these are all straightforward ordinary differential equations. Variable separable, yah. Variable separable, then? Yah, so all that techniques only you have to use that here, okay. Again I am depending, that is only to get the relationship between 2 components, right. So that is what. So like that we have to solve this and then try to get in fact, it is being solved, and this kind of, this kind of reactions, this is K2, this kind of reactions and then a lot of information is available in any textbook. And Lyonsfield is again, actually it is not Lyonsfield, I think before Lyonsfield I think there are some Germans people who have done this, actually that graphs. A lot of graphs are available for the relationship between CR, CS, CB, CA in one graph, okay.

Given if it is a continuous reactor, I think it is expressed in terms of K1, Tao also. K1 Tao is the Dam Kohler number 4 first-order, yah. That is one, in terms of reactor volume is one, the other one is plotting CR by CA 0 versus CA by CA 0, okay. CR by CA 0 versus CA by CA 0. CA by CA 0 will give us what is the conversion, correct no. And for that corresponding conversion, what will be CR by CA 0, which depends on K1, K2 values. Of course, it also depends on CB values, CB 0 and all that, so these are the variables. So you are now increasing more and more variables, because you have more complicated equations, so that is why you will go to multiple reactions more and more but it will be more and more mathematical techniques.

Good, okay. So that one I think kindly go through that and I will give only as far as possible in this section is concerned very simple thing because I think I do not want to pain you also too much with this. But again I think I can tell you, actually this is, what is more interesting in this, okay. Because there is no simple reaction A going to R anyway but in University always be start with A going to R. Luckily we are not talking about the order because there is nothing to talk about 0 order, so that is why. Because independent of concentration, any reactor is okay, so even if you put all those things in your pocket also, they will react, okay.

So that is why they are not talking anything there. So that is why this multiple reactions, this is where I see the awkward face of CrA, awkward face. Why did awkward? Because our brain has to work, so that is why we feel it is troublesome, oh my God, too much of mathematics. But those people who love mathematics, tremendous amount of information, your passion can be put in these solutions. That is why that (())(63:30) was the 1st person for various conditions what could be the CR Max, the yield max. Denbigh is another person, okay, these 2 and there again few more reactions, which, these 2 are very famous most of the times, okay.

Now quickly I will go to Denbigh reaction, then it is not, do not take much time. Correct no, I think you are able to get these points no, why we are, in multiple reactions be on simple A going to R going to S and also A going to R and A going to S, those are the simplest schemes, beyond that it is only the mathematic that is required, rules are same, only you have to carefully integrated differentiate for maximum and all that. But techniques are required for that, right. And slightly complicated like this if you go, then you should be able to get, you know to solve finally, you should have also relationship between other components like CR, CB, CA, CS and good, yah.

So now let us see Denbigh reactions, in fact have not written here. This is only for PFR what we have written, I mean these things PFR, okay, yah. So the same equation, okay, this is PFR , that is somewhere I have to mention, this one, integrating equation for PFR, please write that. Otherwise remember, no one will accept anything whatever we will see. For PFR you will say yes, for MFR the will say yes, okay. Good. So that is the one. If it is mixed flow, what you will do with that equation?

Student: (())(65:13).

Professor: Pooja, mixed flow is the simplest one , tell me then. The simplest 1, mixed flow. These are integration in mixed flow? Then what is the DC, DCR and DCA? That is all, that is Delta, that the Delta CR and is that CA. And what is Delta CA? CRF minus CR 0, CR 0 equal to 0 here, okay. And Delta CA? It is not CA 0, it is again… In this case only CA 0, you know. The definition is always, yah, out and then in. Okay, so that invite is the simplest one, that is why you do not have to really very, that will give very quickly the relationship between CA and CR.

Okay, so that is why you can imagine now that if and all I give this, mixed flow I mean because there is no integration. Very simple straightforward, okay. So that is why, I think you know you can also write for example, DCB by, DCR by DCB, correct no, then you will still get the relationship, right, yah, so that is why. Okay, good, so Denbigh reactions let us take. So that is why, MFR please make a note of that, it will be Delta because there is no integration there.

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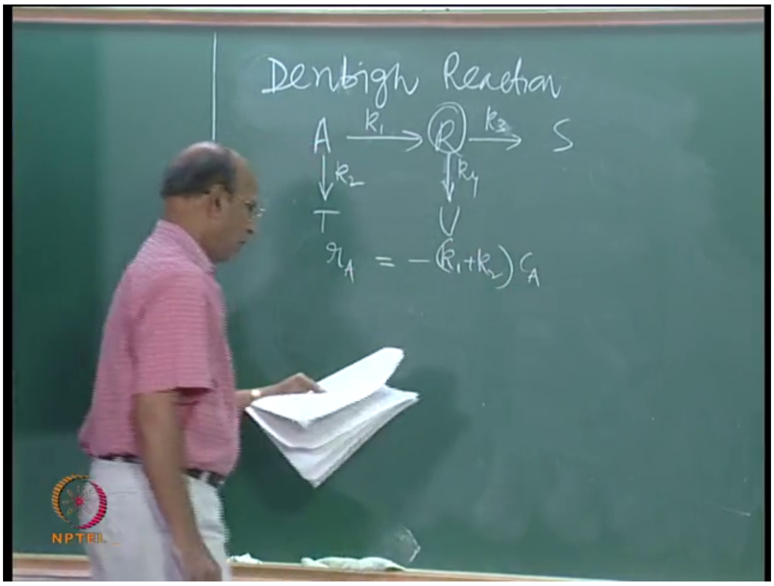

Denbigh reaction, yah. This is again simple scheme that we have A going to R, R going to S, this K1, K2, no, I think yes, I am using Lyonsfield notation. This is T, this is K2, this is 4, K for and this is U, yah. So this is 1, 2, 3, 4, this is the one. And here most of the time it is taken as elementary reactions that means this, this, this, all these are first-order reactions. Okay, so what kind of concentrations I have to maintain?

Student: (())(68:01).

Professor: Independent of concentration. Then what is the variable?

Student: Temperature.

Professor: Temperature. So when we have the temperature, then activation energy, E1, E2, E3, E4 will come. Denbigh reaction is very famous for that arrangement, okay. Depending on E1, E2, E3, and E 4 values, E means activation energy values, what kind of temperature you put. There is no one temperatures scheme like, you know you cannot always high temperatures, you have to use till some point high temperatures and beyond some point low-temperature. That means you have to now reduce the temperatures. So somebody you have heating, somewhere you have cooling, okay.

So that is why thing when time comes, I will also just indicate, you know and the rule is same, what is the rule, if the desired product has, if the desired reaction has more activation energy, then maintain the temperature as high as possible. That same rule only but how do you put that, depending on U, because now for parameters are there, E1, E2, E 3, E4. So whether E1 is greater than E2, one simple thing gives that E 1 is greater than E2 greater than E3 greater than E 4, what kind of temperatures seem you get. Already she gave the answer. So than the other one is the reverse, okay, E1 is less than E2 is less than E3 less than E 4, then what kind of temperature progresses.

Desired product is R. I think that, I think there are possibilities, (())(69:42) you have one of that. That is simple straightforward thing E 1 is greater than E2 greater than E3 greater than E 4 but there will be another combination like okay, E1 is greater than, yah, E 2 but K 4 is greater than K 3, okay, not K3 but E3 and E4, so all combinations are also possible. So all combinations are not possible because it is not in our hands, we cannot say you have reaction, you have only this kind of activation energy. If you are able to tell that it is fantastic, but we are not able to tell that area.

So that is why rules are same, you have to believe me when I say that concept you have already learned because now temperature you should not forget, concentrations you should not forget but in all these reactions where temperature, the concentration is not coming, it is independent because of all that, the same, the same order of reaction. But (())(70:31) reaction is not a modern again, it is different order. On reaction is different order, another reaction is different order. There you have again concentration problem as well as temperature. So that is why it is more complicated. In 1960s and all that you know it is a beautiful playground for chemical engineers.

Football you know, it you can wonderfully play cricket, football, anything you can play there. Because there are so many wonderful problems, even now there are but I think you know those people had really excellent way of solving the things because that is the 1st time they are doing no. All these problems but now with ever more knowledge, more technology, more cellphones, more you know pushing like this, pulling like this, tap like this, anything will work for others, technology wise but brains (())(71:18). All thought experiments they have got, that is why it happens.

Whenever technology increases, brain takes rest. That is the problem, that is why whether technology is really good or bad, highly philosophical people will discuss that. Till what extent technology is really good, entire world is obese, except Ethiopia and one more country is there, Somalia, Somalia only skin, okay, and only skeleton is there, very sad. Except those parts, most of the population, now we have 7.3 billions or something, okay, I can tell you, 7.3 billions are obese. Why? No physical work, no metalwork, correct no. If you want to go, go and sit down in flight, that takes you, you would have to work.

Okay, from here to again to airport, you go by car, no walking, right. And our body is designed only for walking and working and working I say, not for travelling by flights. Really, it is not, it is not designed for that, it is only for working. Hard work, hard work, hard work, when you do that, you will not have any what is that… Really, you have to work hard and hard and hard, so then only your health also is very good. Okay, otherwise what you do, except eating, what else you are doing, tell me? Only eating, that is why you come here and you enjoy my drama and go on eating.

You go and eat in (())(73:03) what is that, your mess, then you oversleep. And tomorrow morning, Monday morning when I ask you, you see I overslept. Naturally if you will eat more, you will oversleep, okay. That is all what you are doing, that is why so many hospitals, that is why so many doctors. If you want to avoid them, work all the time, okay. So because as if you are saving this planet, we have designed cars, we have designed flights, we have designed cycles, we have designed many many things and you are destroying the planet indirectly no. All this is only indirectly destroying the planet.

If our brain is not there, then happily like monkeys climbing here and there and you may have there. You do not know whether they may also have IIT's, you do not know, all monkeys, because we do not know their language. So there may be a Lyonsfield there in monkeys, then maybe an Einstein who has really thought, you know. So that is why there is a wonderful movie called Planet of the Apes, it is really beautiful satire, you know the other way it is always we are paining them, at least once in the moving at least let them pain us, at least in the movie.

That is a really beautiful concept again, that is the greatness of mind again. Okay, that is why we have to just right now, actually concentration scheme is not that great here but with only the temperature scheme which is really good on and even then be applied the rate of reaction equations. And when I write rA, only once, okay, of course this given K1 and K2, than I have the minus K1 plus K2 into CA, that is all now. Yah, and Lyonsfield nicely, his brain is excellent, he will write K12, because he knows how to simplify things you know. K1 plus K2, together he writes K12 there, okay 1st because simply, minus yes, minus is there.

So now shall we continue or are tired of so many things? I think, I am talking about equations, not leaving, not leaving, equations okay. So lets R, what is next one, rR, so rR is the desired product, then it will have CA a minus K3 plus K4, you, what is that, CR. So Lyonsfield again if I write, K1 CA minus K 34 CR, so this is equation 2. Correct no, I think this all of you have got it know? Because this is only participating in K3, K 4 and forming here. R is formed in this reaction, that is K1 CA, this is reacting, this is reacting, so minus the site, okay, good.

So then RS equal to, see I told you no, youngest brother, youngest sister, K3 CA, CR, K3 CR, this is equation 3. Then RT, yah, very good, K2 CA, this is 4. And RU? There, very nice, you have earned your lunch, nicely told. Okay, I think few integrated expressions I will write for batch and PFR, okay. So anyway, beyond this way also have this material balance which is required for us, that is CA 0+ CR 0+ CS 0+ C T0 + CU0 equal to all that again, CA, CR, CS, CT, CU, okay. And of course, if you do not have R0, S and all, that will be 0, then it will be only CA 0. So that relationship is there.

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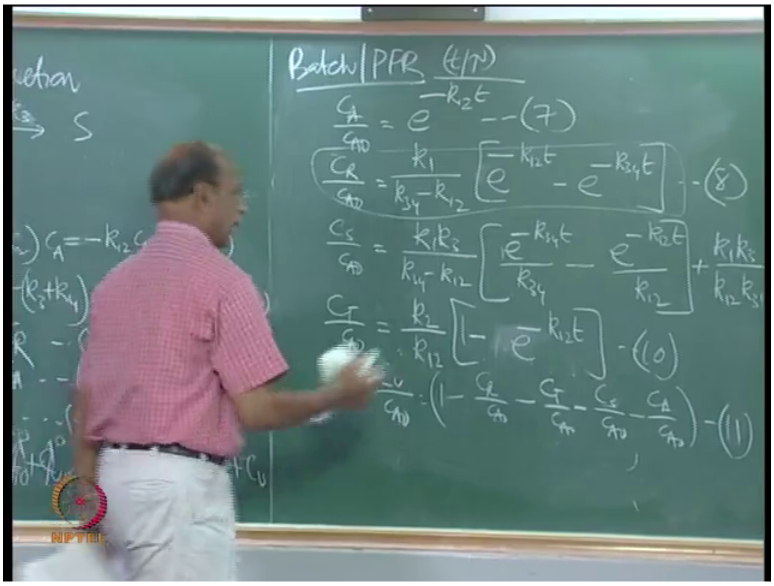

And for batch CA by CA 0, when I integrate, this we should guess no, what is the question for CA by CA 0, by this time you should guess. Yah, something happened to Pooja, yah. K12, tR Tao, I think now. This is what, I think this equation, this is 6, this is 7, yah. So now CR buy, I think here things are slightly complicated, okay. So here let us take , yah, all these things are 0, 0, 0, 0, only we have fluid component A. So now CR K1, K 34, K 12, e minus K12 t minus e power, yah, K 34, K 34 t, that is all. Yah, can you have some comparison between this and water of the earlier?

This is K1 by K 34, K12, exponential K 12 t and is exponential K 34 t, yah, I would only. That is, it is in series, yah. Okay, so then CS by CA 0, this is slightly complicated because this is coming at the end. So we has K1, K 3 by K 34 K12, e power minus K 34 t by K 34 minus e power minus K1 t by K12, right. Plus you have one more term here K1 K3 by K12, K 34, this is 9. Okay, so normally you were desired product is this, you can leave it there but just to, just writing the other things, you get the, you get this. So then CT by CA 0 equal to K2 by K12 1 minus exponential, okay, e power only I am writing, e minus K12 t.

So this is equation 10 and of course CU you can get it, Ct, yah, as minus of 1 minus of all those equations. Correct no. Yah, so that you can write, that is I think CU by CA 0 equal to 1 minus, CR by CA 0, CT by CA 0, CS by CA 0 and minus CA by CA 0, yah. So now one finger is that you know, our idea is to integrate, to get the maximum of this, CR, okay.

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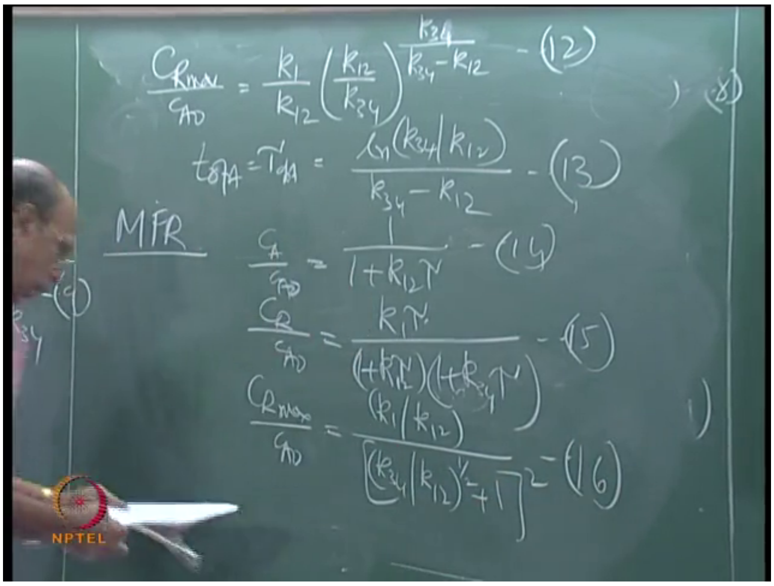


$$\frac{C_{R\,max}}{C_{A0}} = \frac{k_1}{k_{12}}\left(\frac{k_{12}}{k_{34}}\right)^{\frac{k_{34}}{k_{34}-k_{12}}} \quad -(12)$$

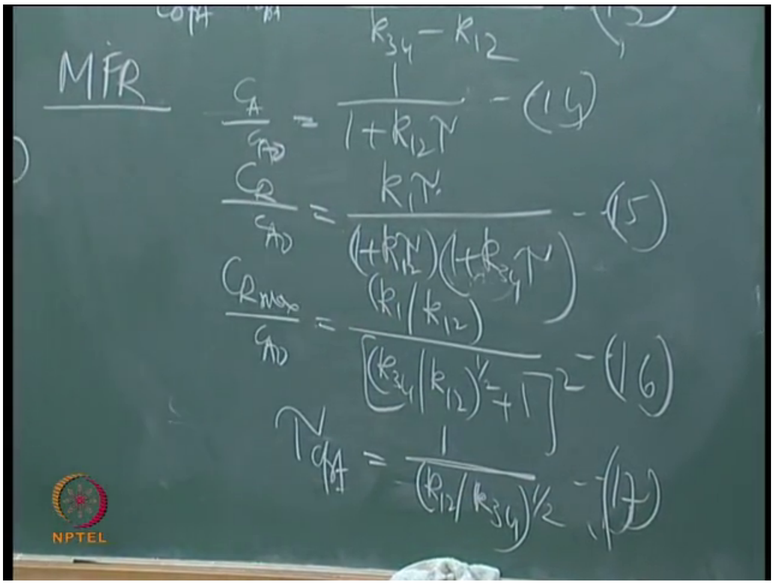
$$t_{opt} = \tau'_{opt} = \frac{\ln(k_{34}/k_{12})}{k_{34}-k_{12}} \quad -(13)$$

MFR

$$\frac{C_A}{C_{A0}} = \frac{1}{1+k_{12}\tau'} \quad -(14)$$

$$\frac{C_R}{C_{A0}} = \frac{k_1\tau'}{(1+k_{12}\tau')(1+k_{34}\tau')} \quad -(15)$$

$$\frac{C_{R\,max}}{C_{A0}} = \frac{(k_1/k_{12})}{\left[(k_{34}/k_{12})^{1/2}+1\right]^2} \quad -(16)$$



MFR

$$\frac{C_A}{C_{A0}} = \frac{1}{1+k_{12}\tau'} \quad -(14)$$

$$\frac{C_R}{C_{A0}} = \frac{k_1\tau'}{(1+k_{12}\tau')(1+k_{34}\tau')} \quad -(15)$$

$$\frac{C_{R\,max}}{C_{A0}} = \frac{(k_1/k_{12})}{\left[(k_{34}/k_{12})^{1/2}+1\right]^2} \quad -(16)$$

$$\tau'_{opt} = \frac{1}{(k_{12}/k_{34})^{1/2}} \quad -(17)$$

So to get that maximum, we have the equation CR max by CA 0 equal to K1 by K 12, K 34 to the power of divided by, this is equation 12 and corresponding t max, not max, optimal, or how optimal for PFR, yah. So that is the one because that is again similar to your series reaction, correct no, exactly series reaction but the only thing is you have more constants that are involved there. Yah, so quickly now writing for MFR, this is very nice, simple, CA by CA 0 equal to1 by 1+ K12 Tao, this is 14, CR by CA 0 equal to K1 Tao, 1+ K1 Tao, no, not K1 Tao, this is K12 Tao, this is K 34.

In fact we do not have to worry about this because these equations are similar to only A going to R, R going to S, okay. So the other reactions I do not want to write there are but I do not want to write, but you can simply say CR max by CA 0 equal to, this one K1 divided by K12, yah, now this is K34 by K12, this is has +1, this whole thing is bad, so this is 15. So corresponding Tao optimal equal to 1 K12 by K 34 to the power of half. So this is 17, very good. Right. So I think you know, you do not have to worry that much even for examination because the same similar things you know A going to R, R going to S only, in Denbigh reaction, if R is the desired product.

I can guarantee that I do not want any other desired product, R only I will ask, if I ask. Okay, yah, so the last one, the one I just mention. Van de Vusse reaction, Denbigh reaction have not given the reference, so you note down, I think the 1st title, Denbigh reaction, you write CS, you know what is CS?

Student: Chemical engineering science.

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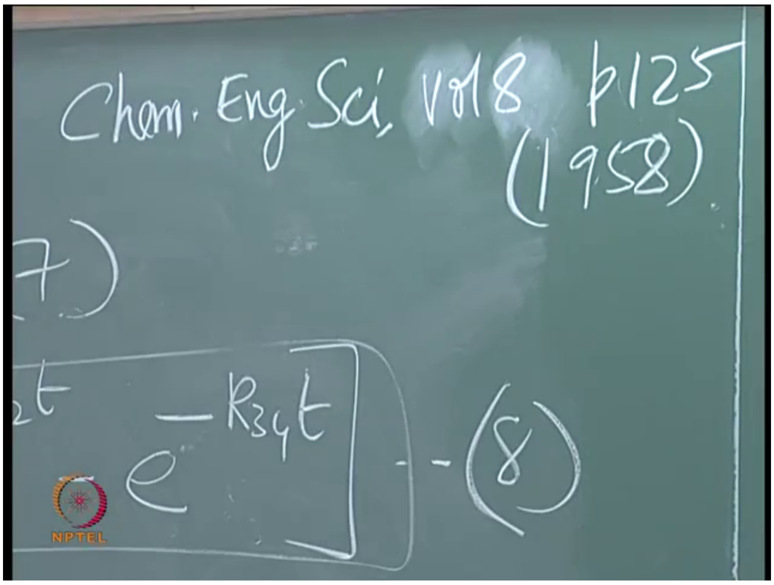

Professor: Okay, I will write Chem Eng science. Normally we write like this, volume 19, I think 1st time I have to tell you, volume 19 and page, sorry, not 19, volume 8, page 125, year is 1958, yah, I was 10 years old at that time. Normally we give starting page, okay. So normally we give starting page, some journals give you complete pages, so then when you go, then only you will know how many pages it is, okay. So this Van de Vusse reaction of the, that is chemical engineering science, this is volume 19, volume 19, page 994, this is 1964, okay.

Actually you see, again that is a beauty there, 60s and till 70s, whatever problems they did, all of them are connected with industry. Afterwards only we lost touch with the industry. There is a beautiful story, I think you know, to lose that connection with the industry, only 1 book is responsible, can you guess that book? That is a book which was responsible for chemical engineers to move away from the industry. Chemical engineers means academic chemical engineers. Right, because in that book what it was shown was, even earlier it was thought that all engineering problems can be solved only by either experiment or empiricism.

That is why you have so many empirical equations for heat transfer coefficient, mass transfer coefficients, all the things, even friction factor, all these things only empirical correlations because they do experiments and then try to extend, scale up a little bit and then try to find out the correlation is valid, fit is not valid, they add some more terms, then they go bigger and bigger. So in 1962 when Bird, Stewart, Lightfoot came and wrote this book, then all academicians thought that my God, what a beautiful idea because all the problems can be solved in terms of differential equations and integral equations.

It is wonderful, idea is wonderful but we do not do how to use it. So that is why all academicians now started working only in problem-solving but not the problem formulation. But in industry there was an existing problem, they have to solve that, but here we will simulate all problems, so that is why we will see that, okay, what difference is equation, 10 boundary conditions. Each boundary conditions will give me paper, it is paper publication only it became. It is not the solutions which we are providing industry, it finally became you know paper publication number increasing, no challenging problems, challenging problems in the industry, what I mean is that, okay.

So that is why, then industry people, when they have a problem, they used to come to academicians, at that time before the 60s and all that, perfect coordination between industry and university. When this book came and when we started solving problems on the paper, and also using different techniques, different techniques to solve the problem, when the industry person comes and asks the professor, then he will talk in his own language. What is his own language, matrices, vectors and tensors. That is our language, right, I think in thermodynamics, in transport phenomena you will see this in next semester.

Only vectors and tensors, okay, then industry person ran away because what is this vector, tensors, I have not seen in the industry. He has really not seen in the industry, then they tried sincerely, maybe 10 years, 15 years, 30 years and then they thought that, okay, all professors are separate breed, we are separate breed, so now the gap widened. So they now stopped coming to universities and then they started their own industrial research. Because they need, there are some problems where industry may take time, it is not instantaneous solution you will get.

So that is why let us have a own RND in industry, so who will look into some long-term problems and much more long-term, even then there was slight contact between industry and university with more complicated problems which they know you cannot solve that problem, that problem only will be given to the academic institutions. They do not expect anything, okay, as you something,, no, really, they do not expect anything but if they give the problem, if the solution comes, very happy, if the solution comes, if the solution does not come, equally happy, no problem, no problem at all, so that is how it is, it has gone.

That one book which changed the minds of all chemical engineering academicians. Okay, now only we are thinking how far, how near we have to go to the industry. It is really destroyed, because it is not the problem of the book, it is the problem of a mindset in universities because we would be happy in solving the problems on the paper, differential equations, using differential equations or other techniques, rather than actually going to industrial looking at the problem and solving. Actually those problems also require these solutions, solve it, I do not know whether you heard what is called SMB, simulated moving bed reactor.

Highly mathematical, it is the people are using that, particular Germany is very good in that. Similar to moving bed, highly programmed and highly controlled, you know the similar to moving bed, you know in normal absorption column, at one point they have 4 absorption columns. One absorption column will be, you know maybe half filter, you know you have the absorbent, it is a batch process, the absorbent is in the packet bed, this packet bed moves now, it is not literally moving but I think in the original laboratory it was literally moving also, right.

So in one packet bed you will have adsorption going on, in another packet bed you will have adsorption almost about to completed, then in another packet bed, you have the regeneration taking place. Because you have to use the same packet bed again for regeneration. Right, so, then another packet bed you have almost regeneration completed, then that becomes again fresh adsorbent bed. So all this is programmed, like you know how the beds move or instead of beds moving people thought that let us move the solutions where they are getting adsorbed.

And this is widely used in biochemical reactions where they have, again there is a farm already in the liquid come in the brought they call, reaction brought and the reaction brought is pumped through these adsorbents and the adsorbents will have, different adsorbents, not one single adsorbent. So that means some adsorbents will take some enzymes, some other adsorbents will take some other enzymes and then finally of course that elation will come depending on what what you take out and then you… That is very very complicated, you know this is really high-tech processes in biotechnology, really high-tech, right.

That is after fermentation, after the actual biochemical reaction, how do you separate the products. So that is why even mathematics are really required in this, in the industry. And I think another example also which I can come I think I said that paper, Puja was asking me, that paper where you have Haber reactor and all that, chemical engineering science. No, not, there was another paper which I said chemical engineering science paper no. Chemical engineering paper that Winter Mantell, one person wrote, he was working in anything Bayer company also or Host company I think.

Yah, so he has written a wonderful paper, is all of you are interested, I can send that paper, to the wonderful paper. Where how the chemical engineering started in Germany and what they did and all that. So at one point of time he was also involved in that. It was 1st computer simulation of crystallisation, crystallisation is another very very difficult problem. It is very difficult problem if you want to get the type of crystals you want. Any kind of crystal, no problem, crystallisation is the simplest.

I do not know, I think long time back there was one Tamil movie called Kamal Hassan, Sreedevi, okay, these 2 people, I do not know, it will name is complicated. But it is Balachandran movie where they go to Delhi and then he does not want to live (())(96:47) it will come, yah, that is correct. I think other people may not understand that anyway. In that movie, I think 4 friends are there, in Telugu it is (())(96:59), intermediate is the original. Okay, it is only dubbed there, but there is a wonderful dialogue where all the 4 friends are there, they cannot get jobs and they cannot live properly and all that.

So then the remaining 3 people will try to have whatever life they get. But this fellow will not allow that, I think we will always say that I want to have life only in this way, that is why he says beautifully, if you see, idealism. Yah, if I want to live like this only, I will suffer but if I want to live like any other way, that means by stealing, by robbing, by murdering, also there is the way of living. So when I want to do that, it is easiest because there are so many opportunities for that kind of life. But if you want to really live like an idealist, there is only one way.

That is why I say the truth is only one, truth is only one, whether you talk or I talk all he talks, truth is only one. But for all other people truth is, I think you know, when you want to tell lies, so then you can tell for the same thing you can tell thousands of lies. Correct no, you have not come to the class, okay, how many lies you can tell, you can 1st kill your father, sorry, I mean, father, grandfather, okay, that is one life. You can kill your grandmother, another lie, you can kill someone also, where some relatives, that is another lie and also you can say that you had headache, another lie as you may say that my leg was paining and I cannot move, another lie.

Thousands of lies for the same one thing, truth is only one, correct reason may be only one, you were sleeping, yah. But that is the problem, okay, yah, it is over a, so then what happens to my Van de Vusse reaction? Okay, next class, okay, we will close it. Only Van de Vusse reaction we will take it, thank you.