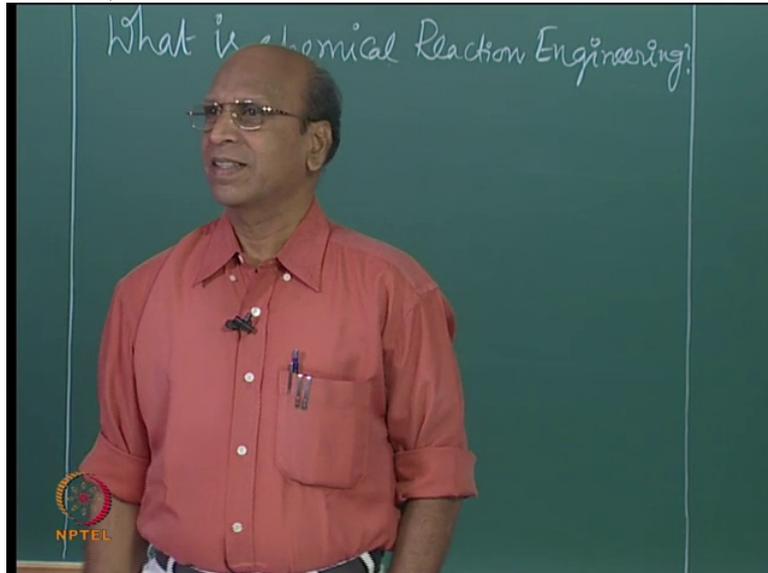


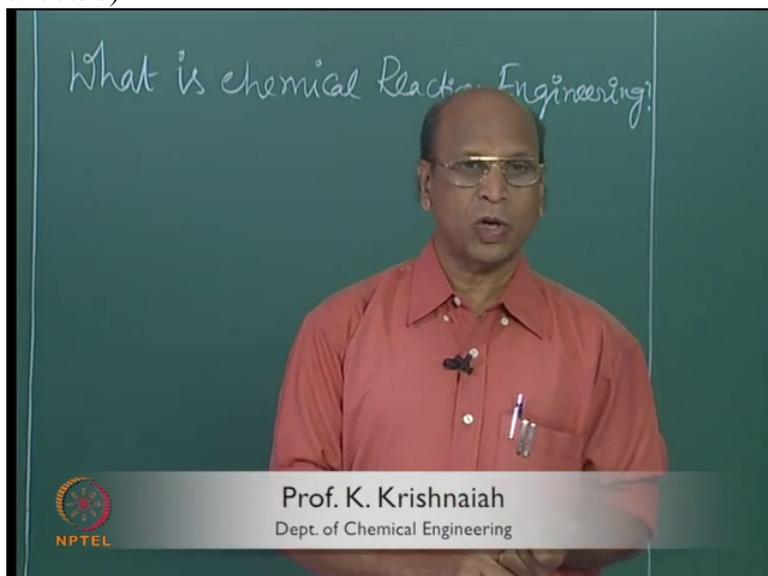
**Chemical Reaction Engineering 1 (Homogeneous Reactors)**  
**Professor R. Krishnaiah**  
**Department of Chemical Engineering**  
**Indian Institute of Technology Madras**  
**Lecture No 06**  
**What is Chemical Reaction Engineering Part 2**

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Ok, I think we have been discussing about this question what is chemical reaction engineering. I have given some examples. Like you know, curd technology, Ok if you really remember even chemical technology also you will not forget and even you won't forget about science, engineering and technology, Ok.

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And as I told you best way to remember is telling to someone what I have told you in the class, Ok. Yeah. In the girls' hostel or boys' hostel if you start telling then you do not forget. Once or twice you tell you will not forget, right? And also we have taken another example that brick technology, Ok. But I did not ask, how do make you know, scientific curd also we discussed, right? When he is taking 10 hours or 8 hours, then you have to go to science

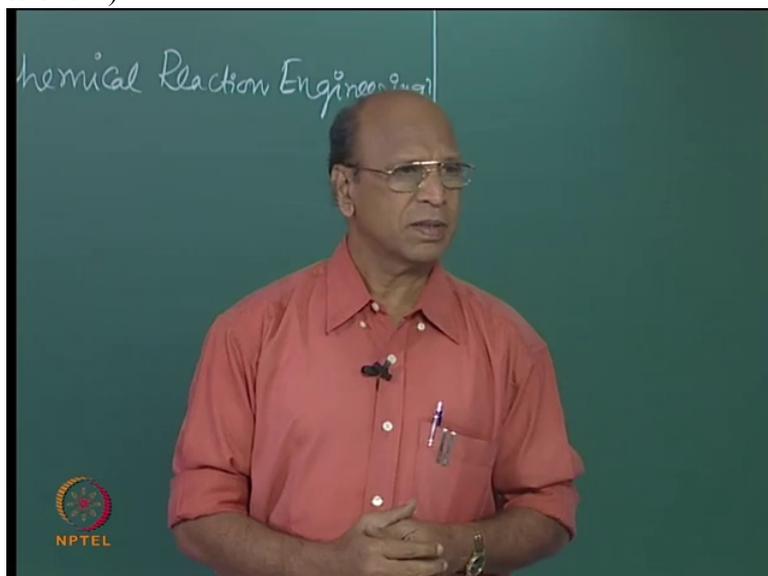
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level of manipulating the genes of the microorganisms then I think you can make really scientific curd.

How do you make scientific bricks?

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Because what we had discussed was simple technology. How much water you have to add and you know, what should approximately the stones in the mud? Alone if you put mud it may, you know melt and it may not have sufficient strength. So that is why. How do you make scientific bricks?

In fact tremendous amount of science is required, yeah, tremendous amount of science is required if you want to make scientific bricks. That means using science, designing perfect bricks. Ok, how do you do that?

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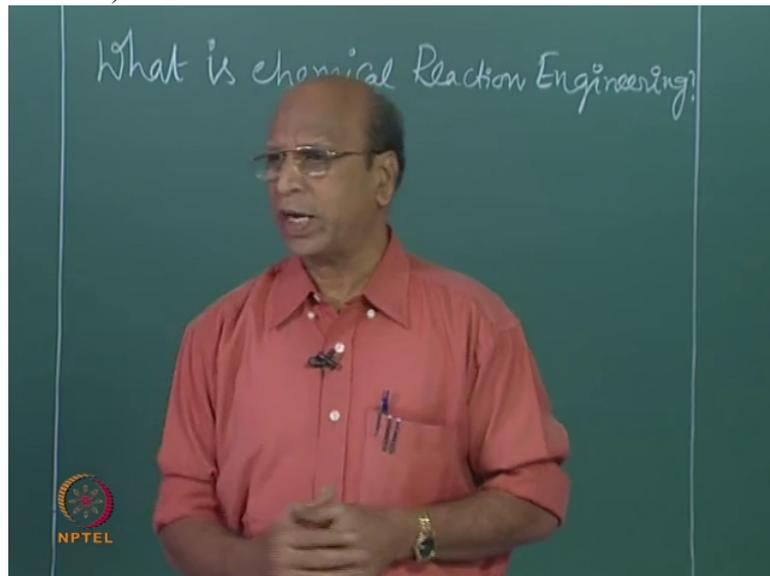


(Professor – student conversation starts)

Student: 0:01:48.2 fly ash

Professor: Do not go to some other thing, we are talking about only mud and sand. Not, fly ash will not give you scientific bricks. What is science in fly ash?

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It is waste. That is why it is science? So what is the science in fly ash? Tell me. If you have some other ideas please tell me.

Student: It is a

Professor: It is a substitute for mud and this, you know, that is all but I am asking how do you now make scientific bricks? The technology we know, the steps we know. How do you make them?

(Professor – student conversation ends)

You have to think no. You have to always extend your brain, what, beyond what teacher told. Then only you know you have that research mind. Teacher tells something. Then you also have to expand on your own, from your brain a little bit, no some other steps, Ok, some other projections there.

Ok, so whatever you believe the teacher tells then you are a good listener. We will accept that. But you are not using your brain to sharpen and also your brain to do something new. This is what is, in fact unfortunately, that is the problem with all our, with the society, our society because that is why we are not able to make good researchers.

The reason is that we always believe elders. Mother and father, whatever they say, they may show bull and then they may say this is elephant, you will say yes, yes, yes, yes. It is elephant, Ok.

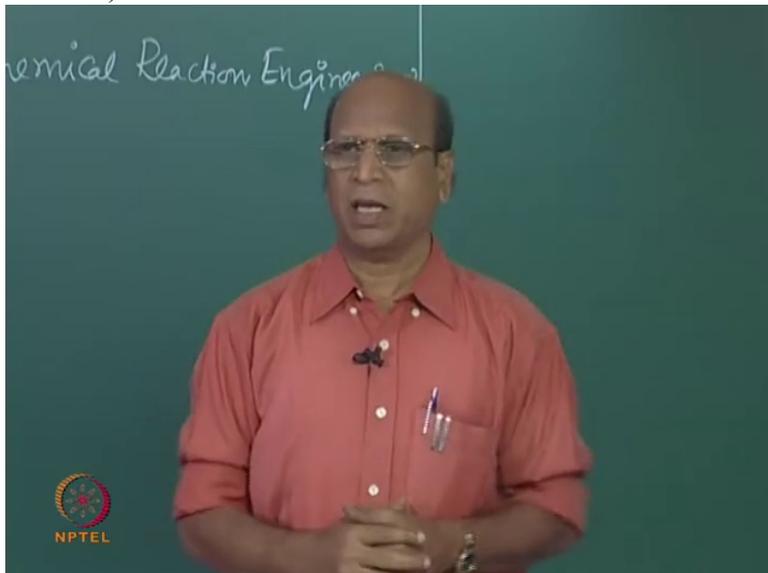
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You do not question them at all. Similarly you do not question the teachers. You do not question yourself. So that is why we have a stable society but again, you know normal society. It cannot innovate or it cannot do something new.

That is why even though our culture is one of the oldest, we could not produce anything at international

(Refer Slide Time: 03:31)



level, producing technology, producing materials, producing some theories, all that because we simply believe God and afterwards we believe our parents and afterwards we believe our teachers. You should not believe anyone of these people which I told. Even you should not believe God, Ok. Yeah. No, if you want to break away from science.

Otherwise you always say that Ok, God gives something, we only use that and even if you do not get food, Ok, today God gave me only one meal. So the remaining two meals tomorrow he may give. At that time we will see. That is why, you know, because where is the, because you are trying to compromise. And in research you should be more aggressive. You cannot be compromising for each and every thing, Ok. So that is why you have to also think.

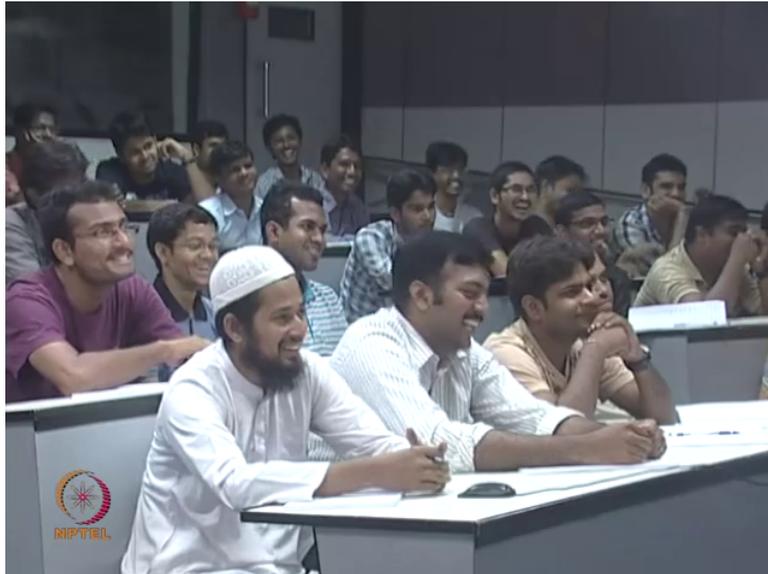
You know, when I told how do you make curd scientifically, you should...two examples only I gave. The other example you should have thought on your own, that how do I make now, Ok he told me how to make scientific curd but now how do I make scientific bricks? So at least at this point of time. That is why I think in schools also we are killing the innovation and we are killing the enthusiasm.

What do we give in school? 10 k gs of books behind the fellow. Ok he is already one foot and above the ground and by putting this weight again you know, anti-gravity it will pull down, Ok, pull down, so I think he also cannot grow faster. Always gravity is acting on him, no. Another additional 10 k gs of 5 k gs load. Ok that is all what we give him. We never you know, allow to, to, to think on their own.

Even if they want, I think you know, there were two ice creams and if one ice-cream is black and another ice-cream is white and this fellow wants to take that black, that chocolate ice-cream then mother, father, no, no, no, that is not good, you only eat this. You have to allow him to eat and if it is bad then he will come back anyway to you if he does not like the taste. But we try to dictate, no, no, no, that is good, that is not good, you only do this, or you only eat this. That is why we are not allowing.

We are doing a wonderful job as parents to all of you, Ok but when you become parents, do not do that. You allow your child to go anywhere, jump up and down; I think ask any question, Ok you have to patiently answer. Then only, I think, do not give them book, do not give him books, do not give him even computer, Ok and do not allow him to see the TV, right. Ask him to think, that is all. Because TV (laugh)

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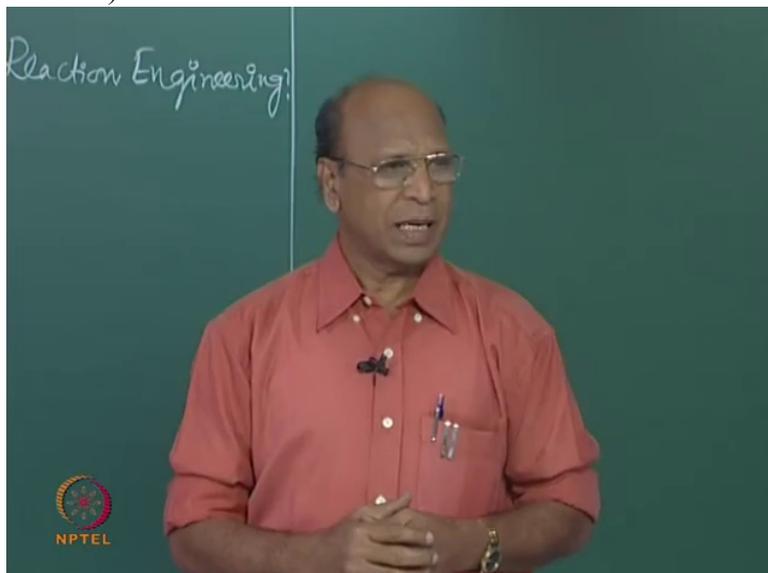


(Professor – student conversation starts)

Student: (laugh)

Professor: That is all, what else is? (laugh) No really, that is what is most important, no? What does he get by seeing the TV? That fellow sits and always look at that cartoons, right. I mean

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cartoons are really innovative if he makes the cartoons, not seeing the cartoons. If he is able to draw on his own cartoons and then make the new cartoons then fantastic.

(Professor – student conversation ends)

And what happens at the age of, may be you know may be third or fourth year he will get the specs. All of us got around 45-50 years but most of the young children no, because of the contribution from TV, they are getting only third year and fourth year itself

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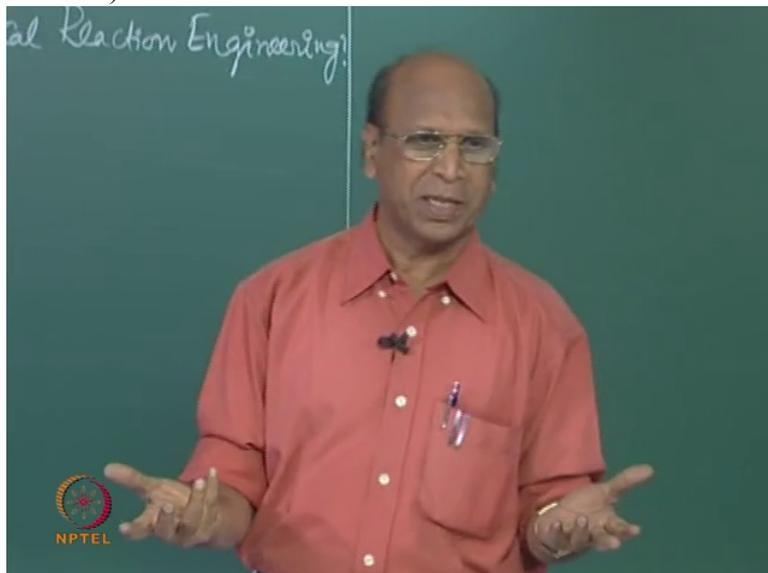
this thick. And by the time he comes to engineering he does not know where to go.

(Professor – student conversation starts)

Student: (laugh)

Professor: Yeah, because the thickness of this thing is so much, light cannot enter, everything is black

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for him. In the mind black, world is black, everything is only black, darkness only. That is why you should have thought no; Ok now scientific bricks; how do you make scientific bricks? Just think. Sorry?

Student: Plastic

Professor: With plastic, Ok why plastic? Ok, that means you throw away mud and then only start with plastic or what? I am given talking about given only mud and you know some amount of solids, how do you make scientific bricks?

(Professor – student conversation ends)

Earlier what we do, the technologist has a feel how much sand should be there, how much mud should be there, he mixes and puts right amount of water and all that. So now I am asking you on large scale produce like a chemical engineer, you produce like any chemical, produce bricks. How do you do that? Ok what?

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(Professor – student conversation starts)

Student: Mixer is required.

Professor: Mixer is required for long time, before that?

Student: 0:07:41.0

Professor: Straightaway you start with mixer?

Student: First is ratio of reactants

Professor: How do you find out that?

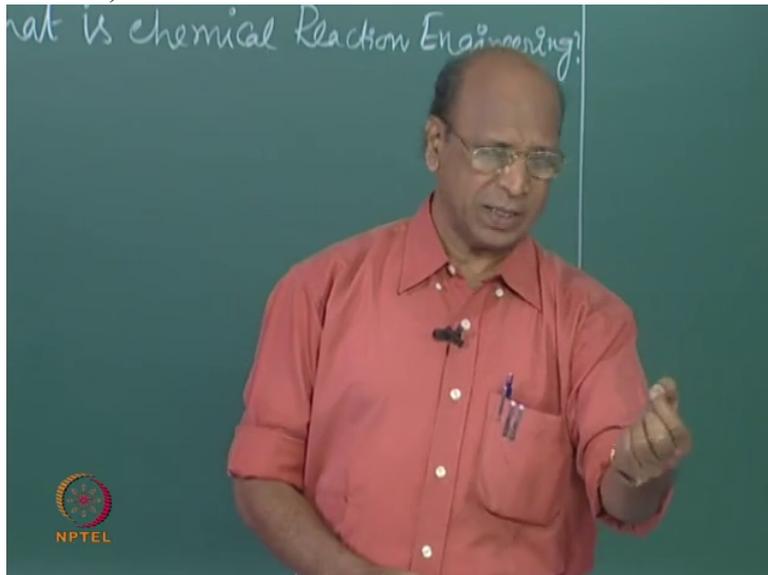
Student: Stoichiometry

Professor: Either trial and error or from theory where what size of the particle is good, for example. What is the particle size?

Student: C E

Professor: Normally they may use 1 m m

(Refer Slide Time: 07:57)



particle, Ok, point 5 m m particle. Why point 5 m m particle is better than 1 m m or why not 2 m m or why not point 1 m m? Sorry?

(Professor – student conversation ends)

Yeah all that is the science. Right, I think that way. Then even if you can go to, Ok, can I use nanotechnology to make bricks? That means nanopowder, where I will bring all the powder together and then put them you know like a puzzle form where children play and all the puzzles together and you have the brick. That is pure science which you cannot realize at this point of time.

You may do it. I told you no, that example where that girl told me how do you make sulphuric acid means hydrogen bring, sulphur bring, O 4 bring and then put together and then give it. Wonderful really if you are able to do the same thing, for even brick, for any chemical. That is what is the pure science. But we are not able to realize that.

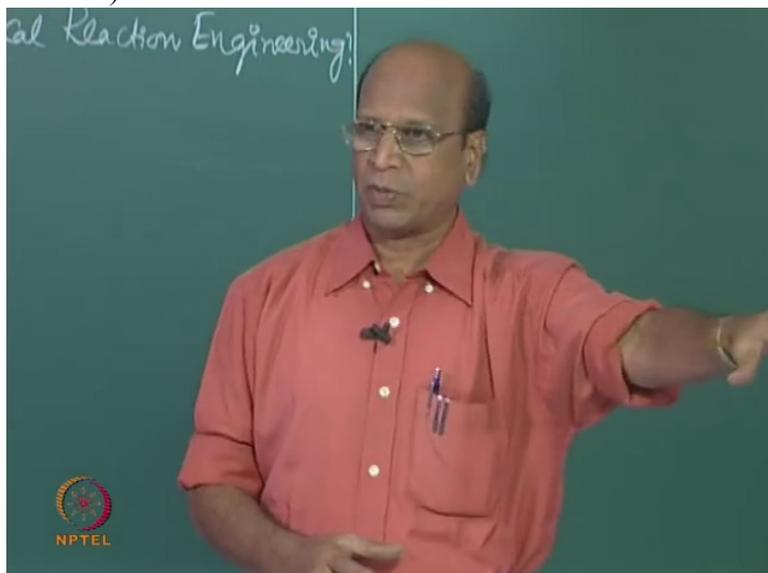
So that is why when you are now going for, with scientific knowledge is how to find out what is the particle size and how this particle should be, orientation of particles inside the mud, how do you arrange them, like crystal structures, right. You know from the basic crystals if you go,

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how beautifully those molecules are arranged in the crystal structure where you have sufficient strength also for those structures. Some structures have

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lot more strength, some structures have weak strength, all that.

So using that science can you also now design your brick? You see for every technology like for example bullock carts. Bullock carts we think that it is lowest technology because no

science is; no equation is used for making bullock cart, right? So then if you really want to design a scientific bullock cart, you need tremendous amount of theory, tremendous amount of engineering.

Ok, in this brick technology once you find out what is the orientation of solids, and what is the right amount of mud, right amount of wa/water I mean water and also particle size all that scientifically when you see and how do you see scientifically? You have to arrange all that and try to find out which gives you the best toughness, strength. That is what is science.

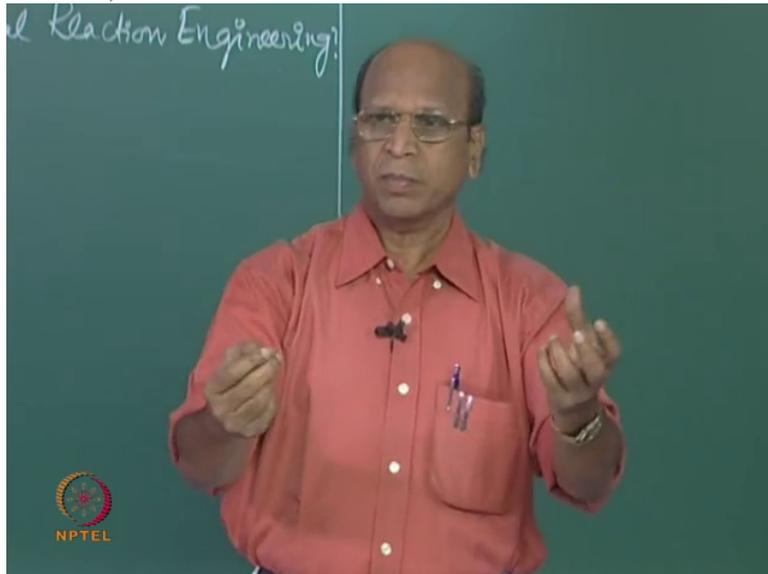
Then afterwards you have convert it into product. So then you have to use engineering principles, as he said I want to have this continuous brick making, so you mix at one point and actually you now need 1 bin with mud, another bin with particles, then both of them will fall into the mixer

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and also another bin with water, right amount of water, all three you know, you should have flow rates,

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Ok, how do you measure flow rate of solids?

Because I know B Tech and M Tech lab, B Tech lab you should have done how do you measure flow, liquid Ok but I think solids definitely you would have not done. How do you measure?

(Professor – student conversation starts)

Student: Look at the mass flow rate

M; But do you measure? Because continuously, no.

Student: Change in weight

Student: Starting point and ending point

Professor: Where? Where is change in weight?

Student: Of the bin

Professor: Yeah means the entire bin must be on a balance where...

Student: Load cells

Professor: Yeah load cells and all that, you know, you see....all that is the one what we have to use. I know most of you have not been exposed to this information.

(Professor – student conversation ends)

And all of us have been exposed to how to measure water flow in the labs. That is why I asked that question so that you can think again. So load cells are there and big platforms are

there, now entire lorries are weighed, you know, Ok, that kind of things you have to think now and then say that, yes how do I measure now solids flow rate?

Because you have to send may be 10 k gs per hour or may be 15 k gs per hour continuously, then mix them. After mixing what it has to go through, like extruder, right and then after that... Ok so at the end, you know the paste will not flow. That is why you have to put extruder. And now after extruder it goes to the mould and this mould must be automatic; that mould, right.

That automatic means you design that mould and then the moment the paste falls there mould is filled up and another thing will come and yeah, apply also sufficient pressure and then mould will go, this will be thrown out directly to, for sintering, drying and afterwards sintering. Ok drying now you see, because it is a continuous system you cannot wait now for 8 hours. Or solar drying means 4 days, 5 days.

So now you have a design a dryer where all these operations must be done very quickly then it has to sinter. Sintering also, generally sintering may take time. But even then, you have to design that one faster. That is what is engineering principles you are using for brick making with the help of science.

Now you define chemical reaction engineering with these examples. Now you define. Because I have given sufficient examples, when engineering comes, when science comes and when technology comes. Forget about technology, now I am asking chemical reaction engineering definition. It is engineering of chemical reaction, Ok so now whatever we have discussed that engineering principles we have to use now for chemical reactions to make them work.

What are the engineering principles which you use in chemical reactions? Yeah mixing is one. Because I think when you take large quantities and then you have to mix them, yeah that is one.

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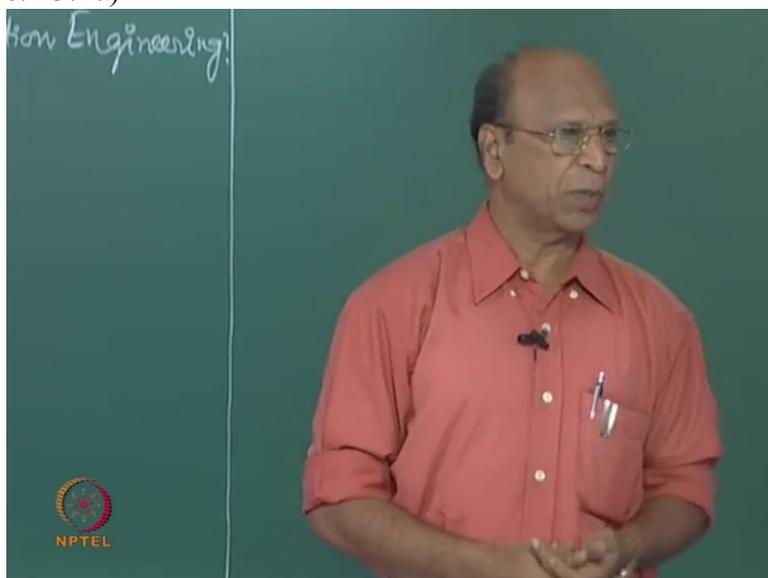
(Professor – student conversation starts)

Student: Unit

Student: flow from

Professor: yeah, flow anyway if is a continuous reactor, flow must be used. That is also

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an engineering principle, fluid mechanics, heat transfer how do you remove heat.

Student: Yeah

Student: Mass transfer.

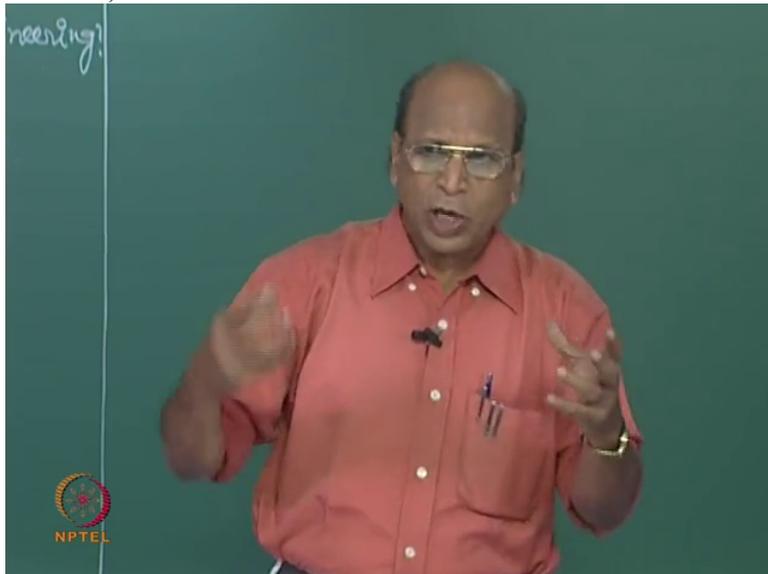
Student: How do you add heat? So that means all engineering principles, when you are applying to chemical reactions

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that is called chemical reaction engineering.

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(Professor – student conversation ends)

See now you do not have even remember that. Because automatically when you know all these sequences, you know the definition already. Correct no, if you remember that curd, if you remember this brick technology, because those two things we told because you know them already. Ok, how to make them, you know.

But now applying those same things here also, applying that engineering principles for chemical reactions like for example the flow, if it is continuous reactor. Even if it is batch

also of course you know how to feed and all that. So then temperature, how do you control. How do you supply heat, how do you remove heat.

And before that you also should know kinetics. OK, what is the type of reaction what you have? It may be having order of reaction or it may not be having order of reaction. That means you need a rate expression. How do you get this rate expression? From experiments, kinetics, that is kinetics studies.

And thermodynamics will not give you rate expression. And thermodynamics will not help you in actual reaction engineering in the sense that for the design. For the design what you use is only rate expression, not equilibrium data, right? Equilibrium data will come if it is a reversible reaction in the equation automatically, you know. What is equilibrium, I mean equilibrium constant, capital K also will be present in the rate expression.

But that rate is important. How do you get the rate? By doing experiments. Or if it is already given this is first order, you simply write  $-R_A = k C_A$ . So all the engineering principles you are using that. And what is the difference between chemical engineer and chemist now?

Chemist will not bother about the flow. Even if he does continuous, but it is only very small quantity where you will put a jar there and from there drop by drop it will fall and drop by drop if you make in industry, you can never make that kind of large quantities. That is the difference between chemist and chemical engineer.

And we need not to blame him. Or he need not blame us. Because that is his duty or her duty as chemist. What is that? To find out how the molecules are moving, to find out how the molecules are reacting. And how do you get finally whether this reaction is happening or not, that information. But his scale always very, very small.

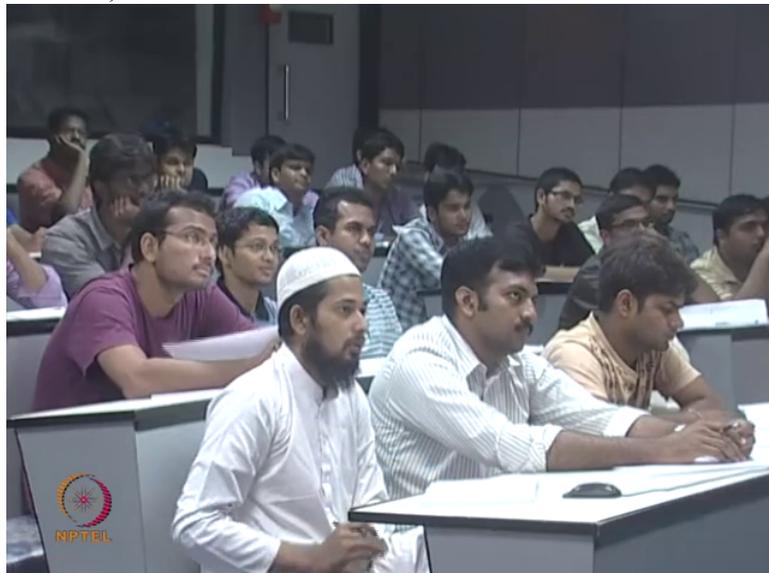
So now you see with these examples, you can even draw the flowchart. If I ask you now curd making flowchart, can't you make now? Easily you can draw the flowchart. For example brick. You know that initially we should have the bins. And then both have to fall. And then

you have the mixer. From the mixer it has to go to again extruder. From extruder it has to go to mould and all that. Now you can imagine any process.

That is why process is important, mind means important. Mind means you know thinking is important. If you think of the process step by step what is really happening, where the heat transfer is coming, where the mass transfer is coming, where the reactor is coming, where the fluid flow, fluid flow is throughout if it is a continuous system, even if it is batch system it is continuous, I mean all the time you have to pump the liquid after the reaction is over to store or you know from the reactant storage to the reactor, so all these things are happening already.

So now that is why even chemical technology will be very easy, you know, by answering these questions what we have. That five questions will give you the entire knowledge, Ok, 5 or 6 questions, right? What is the first question? What is chemical engineering? Then what does a chemical engineer do? Yeah, I think you have forgotten already. What is the third question?

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How does a process flowchart start?

(Professor – student conversation starts)

Student: Flowchart

Professor: And then?

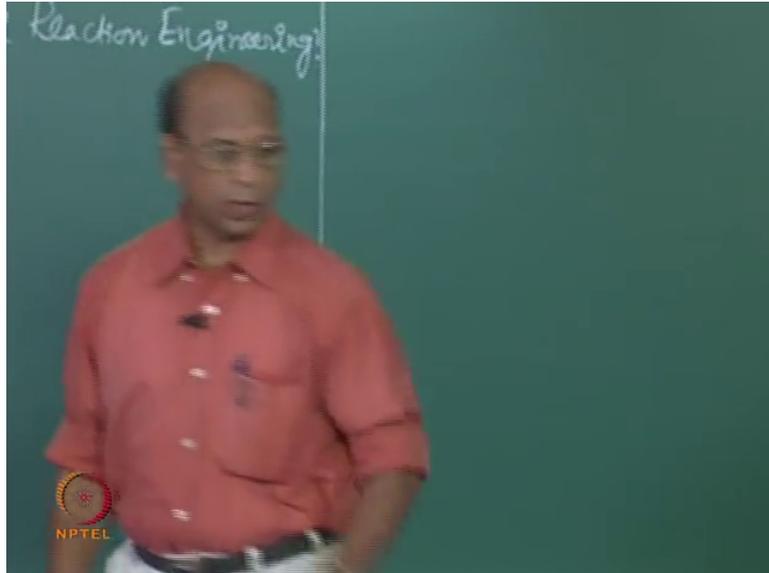
Student: What is C R E?

Professor: C R E means what is the next question?

Student: What is the information required for reactors design?

Professor: That is the question now. What is the information required for

(Refer Slide Time: 17:25)



for reactors design? Ok I think this is very clear now. I think you can...see I do not have to even now define. You know how to define now chemical reaction engineering, right. That is, using chemical, I mean using the engineering principles to conduct chemical reactions. That is all. I think you know the first person who cashed that name after this seminar is over, can you guess who? Who cashed that name?

Student: Levenspiel?

Professor: Excellent. Levenspiel. Immediate he got that name and then put the name of the, name of his book as Chemical Reaction Engineering, fantastic,

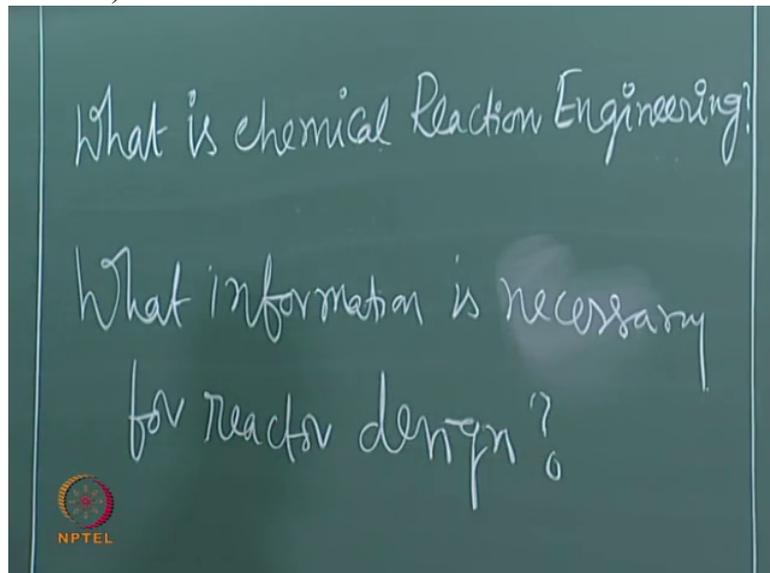
(Professor – student conversation ends)

Levenspiel is really great, the way he makes things simple, Ok. Before that also there are 2 more books. Walas there was a book, W a l a s, Walas, Ok, I think Chemical Kinetics for, no, (Reaction) Kinetics for Chemical Engineers, that is the title. No, not easily read book, it is a good book but not easily read book. Then at the same time, even J M Smith book, yeah Chemical Engineering Kinetics, yeah. So that book also was there.

But those books are not that famous when compared to Levenspiel. Why? Because the presentation, the way he explained things. Presentation is really beautiful in Levenspiel. So he immediately took the name and then put for his book as Chemical Reaction Engineering. Because he has already used that book, you know, Smith recently, maybe I think only 5-10 years back that one, Engineering of Chemical Reaction, again what a wonderful name!

Engineering of Chemical Reaction, that means only he just changed these, you know, words that is all, Engineering of Chemical Reactions, instead of Chemical Reaction Engineering. Ok, so the next question was, yeah, what is that, what is information, what information is required, what information is necessary, yeah, is necessary for reactor design? Ok, can you tell me,

(Refer Slide Time: 19:49)



what is that information required for reactors?

(Professor – student conversation starts)

Student: Rate of reaction

Professor: Rate of reaction

Student: Performance equation

Student: Contacting factor

Student: Performance equation

Professor: Volume of the reaction, volume of the reactor.

Student: Contact

Student: Flow rate

Professor: Flow rate,

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yeah, see you know the volume of the reactor

Student: Performance equation

Professor: You know the rate and you know

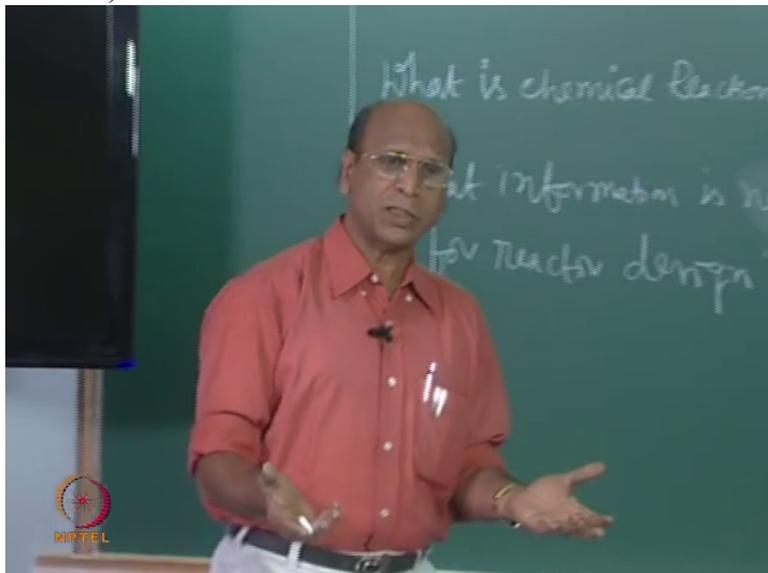
Student: Initial concentration

Professor: Initial concentration, yeah, you also know conversion?

Student: Contacting factor

Professor: You also know conversion, then where is the designing?

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All the questions you know, everything you are telling, that you need volume, you know already conversion, you have to give again, if I give volume, if I give conversion, if I give  $C_A$  naught, if I give rate expression, there is no design, everything is known. Then you have not told tau. Ok, we should also know tau. Ok (laugh). If everything is known, where is the design?

Student: Equation

Student: Amount of the product

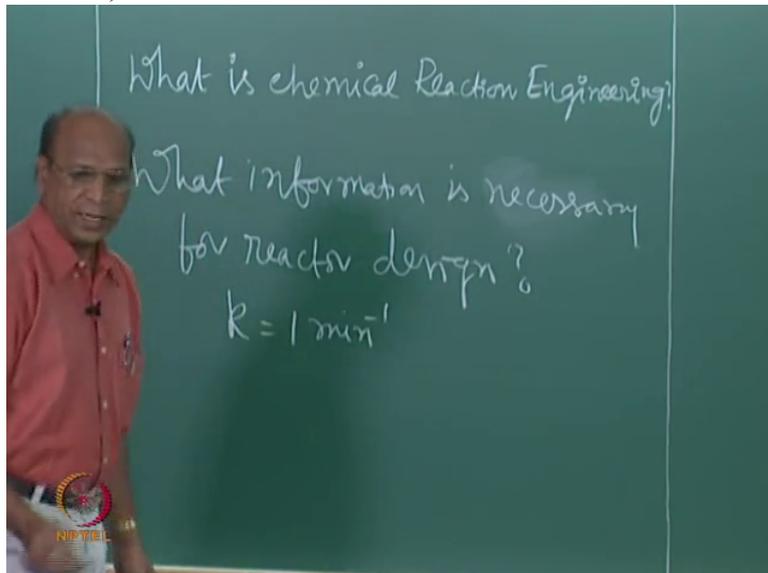
Professor: Amount of the product, yeah that is correct because I think flow rate indirectly, that gives the flow rate. Yield will not come in the design because, where are you using yield to design the reactor? It is always conversion. Because the basic expression is written in terms of only reactants, that is why.

(Professor – student conversation ends)

Reactants only get converted. Ok, yeah but still you have not answered by question, what is necessary, what is information that is necessary for reactor design. Ok I will give you another, some data. You just tell me whether this is just sufficient for reactor design.

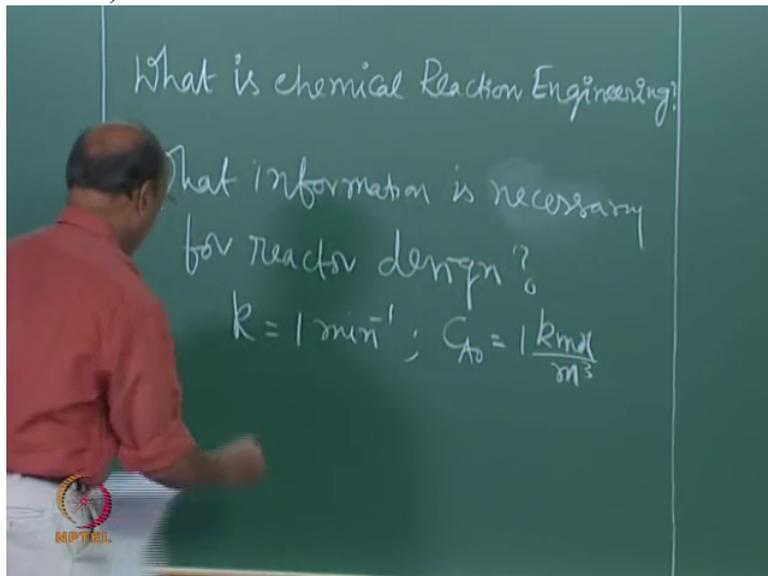
So I give you  $k$  as let us say 1 minutes per inverse,

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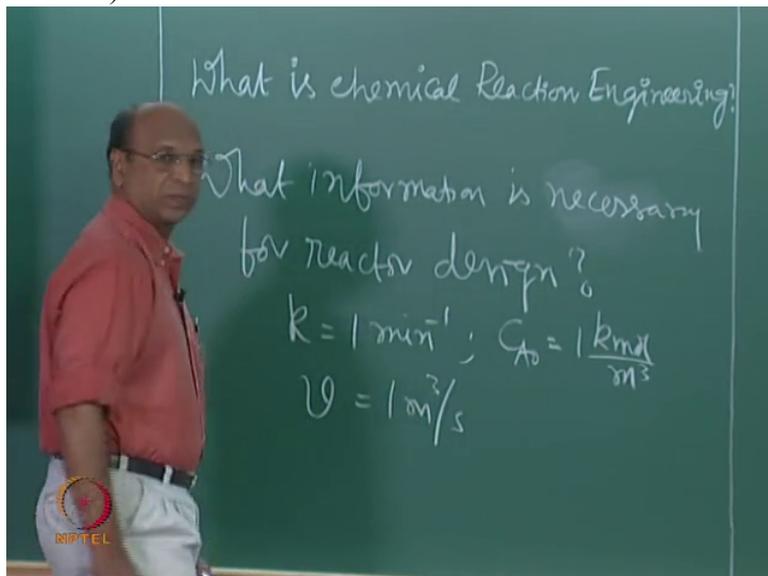
Ok. And then, Ok, I will also give you, someone is asking initial concentration  $C_A$  naught as 1 kilo mole per meter cube, yeah

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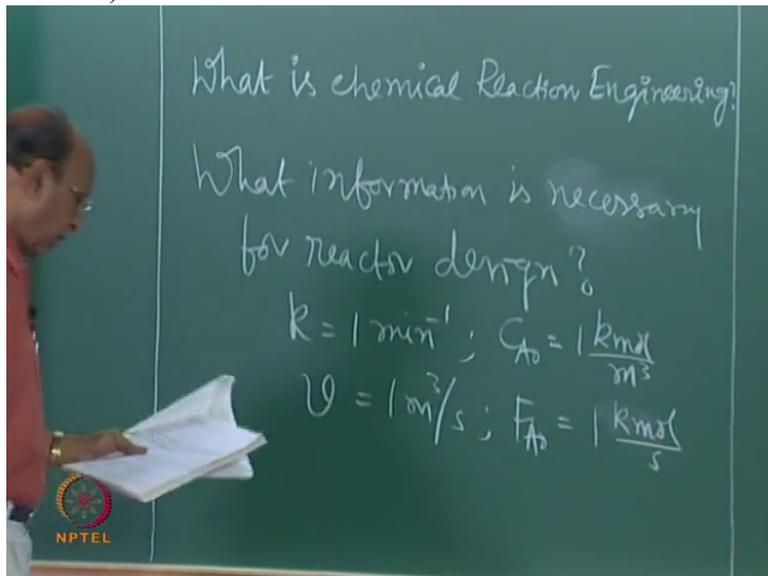
and I will give you  $v$  as yeah 1 meter cubed per second.

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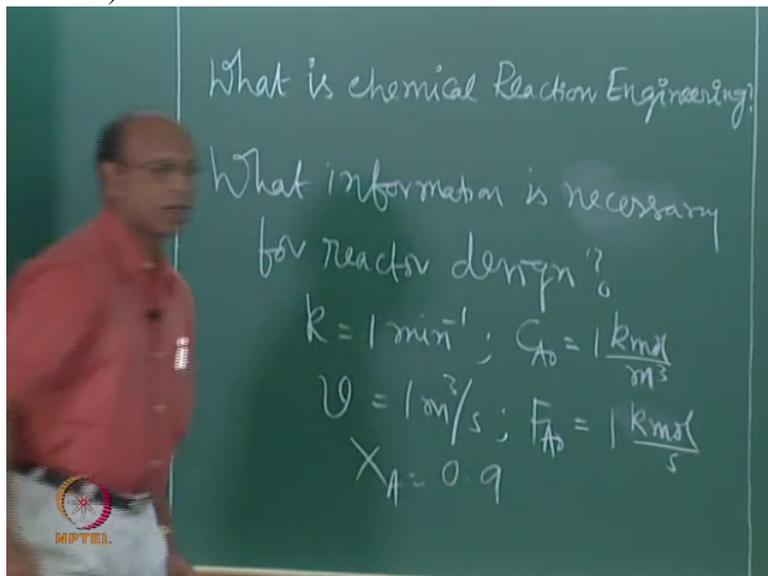
I will also give you  $F_{A0}$  as 1 kilo mole per second,

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Ok. I will also give you  $X_A$ ,  $X_A$  equal to let us say 90 percent conversion.

(Refer Slide Time: 22:11)



Do you have all the data for reactor design?

(Professor – student conversation starts)

Student: Type of reactor

Student: Contacting

Student: Contact, batch or continuous

Student: Which reactor we will...

Student: CST or

Professor: You have to mention that?

Student: Yes

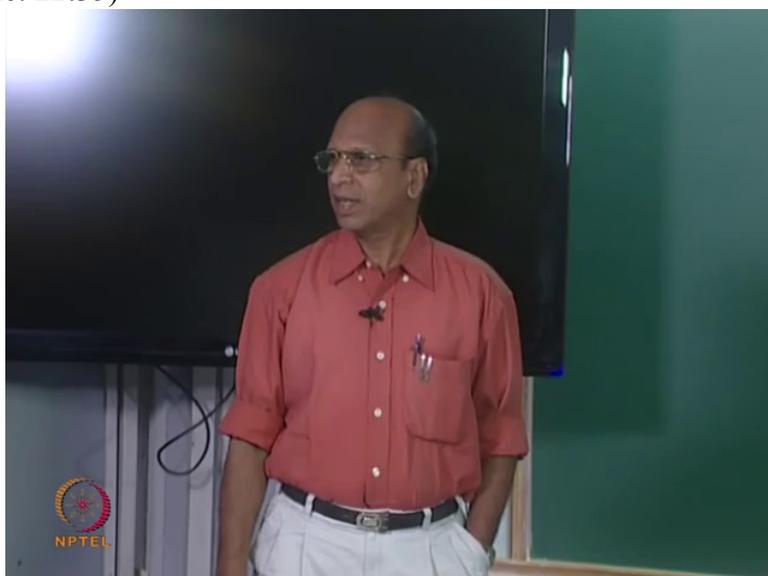
Student: Performance equation is not there.

Professor: Performance equation

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Student: 0:22:36.8

Professor: You have to find out. Say something. Element?

Student: Rate of reaction

Student: Homogenous or heterogeneous

Professor: Ok, homogenous

Student: Rate expression is not given

Professor: Yes

Student: Rate expression

Student: It is first order, we can get it...

Student: Yes, it is first order, Ok, first order

Professor: Yeah it is given as minutes inverse, it is first order which is totally wrong, Ok. It need not be first order for many cases.

Student: Ok

Professor: Because our mind is still L K G that is why all of you say that it is first order. This is truly valid only for homogenous reactions.

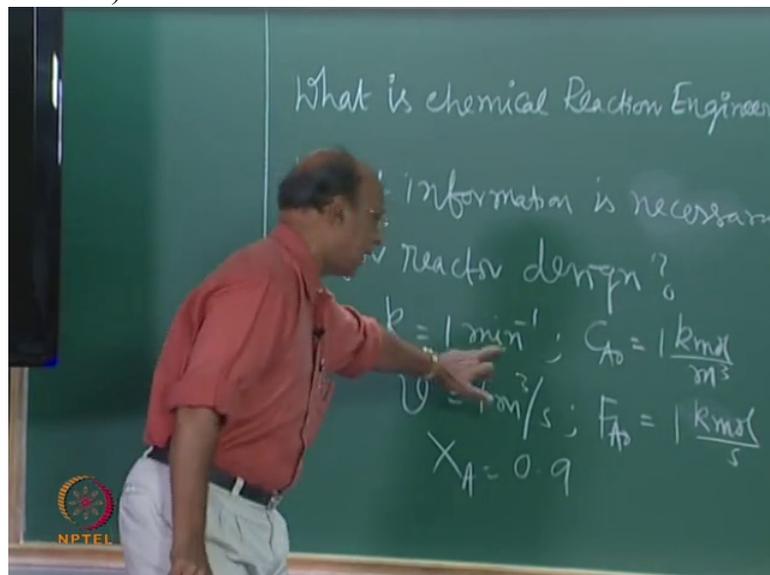
Student: Homogenous, yes

Professor: The moment you go for heterogeneous reactions it may not be that. Because rate can be expressed based on various things.

(Professor – student conversation ends)

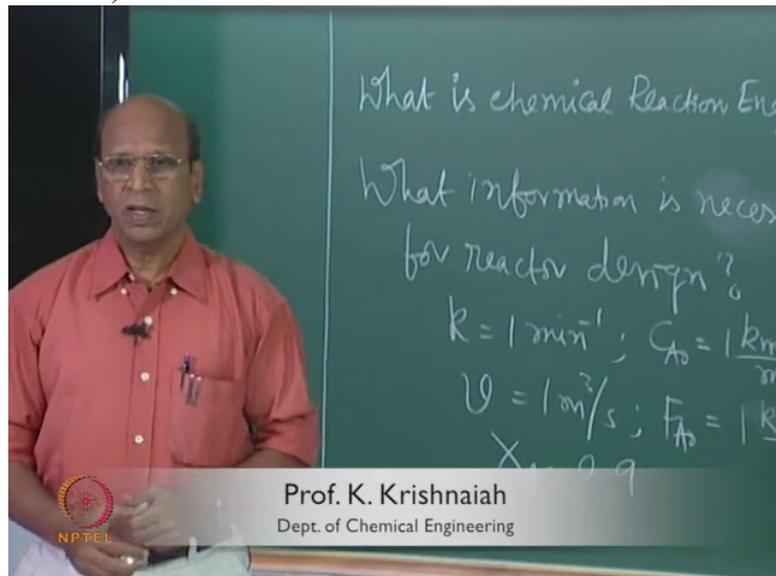
Because homogenous reactions we base normally on moles converted per unit time per unit volume. If you base only on unit volume then, you know, this indication is right

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that this is first order. That is why it is strictly for homogenous reactions where rate is based on that.

(Refer Slide Time: 23:43)



Rate can be based on surface area; rate can be based on weight of the catalyst. Rate can be based on mass; you know surface area, volume of the catalyst, volume of catalyst, volume of packet bed. So there are so many things which you can have. That also we will discuss later. So that is why, yeah, the most important thing which is missing from here is I have not mentioned what kind of reaction?

Ok, then Levenspiel has put all this information that is necessary for reactor design in this wonderful diagram. I think some of you may be knowing because she is telling already performance equation and all that. I do not know how many of you used Levenspiel book. All of you? All of you.

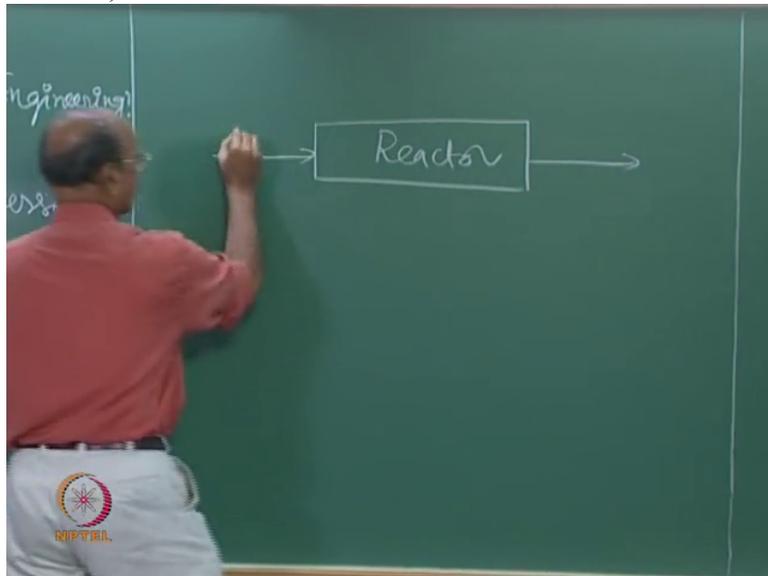
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Then you must know, but I do not know what is meaning, you really know the meaning of this diagram.

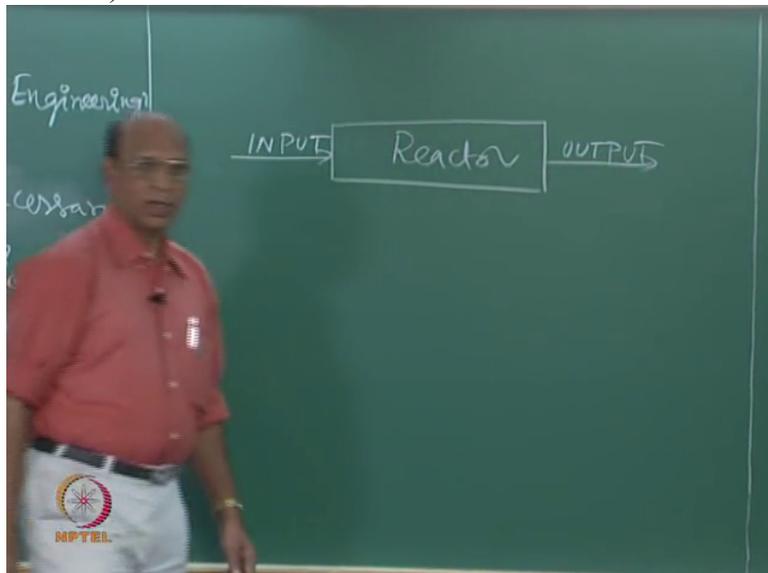
Yeah, what is here? Reactor,

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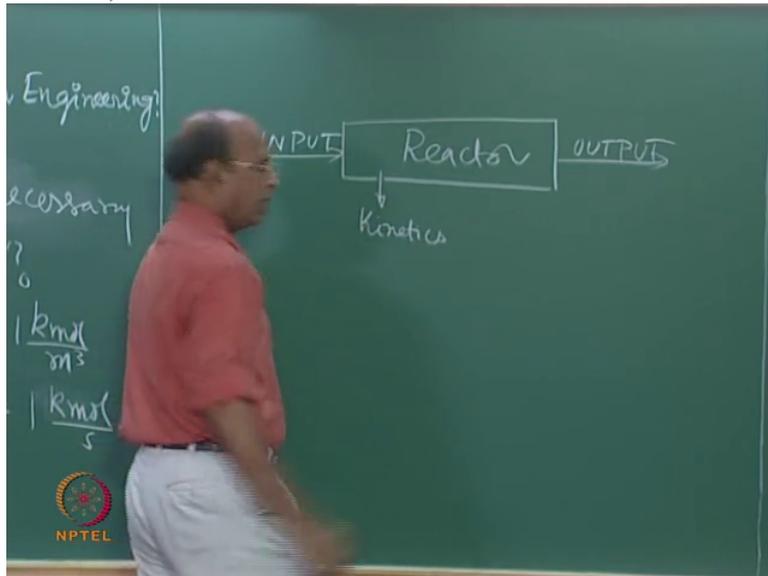
this is input, this is output

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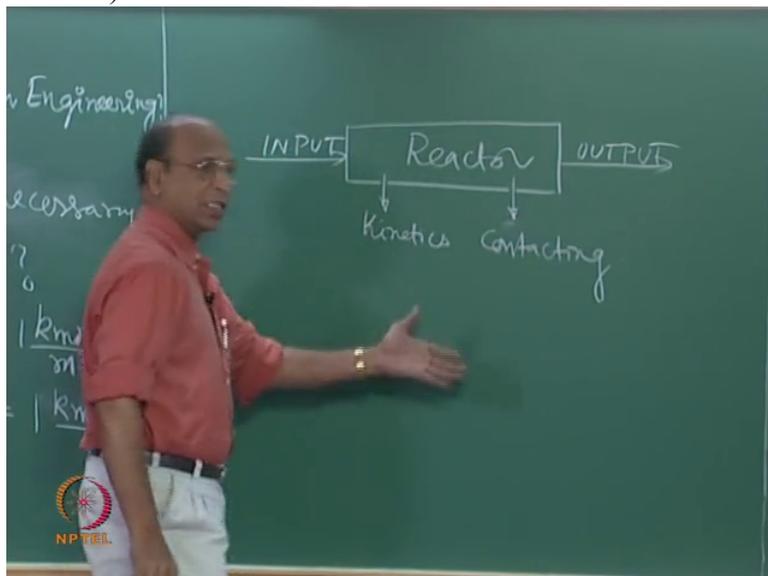
yeah then we have here what is called kinetics and

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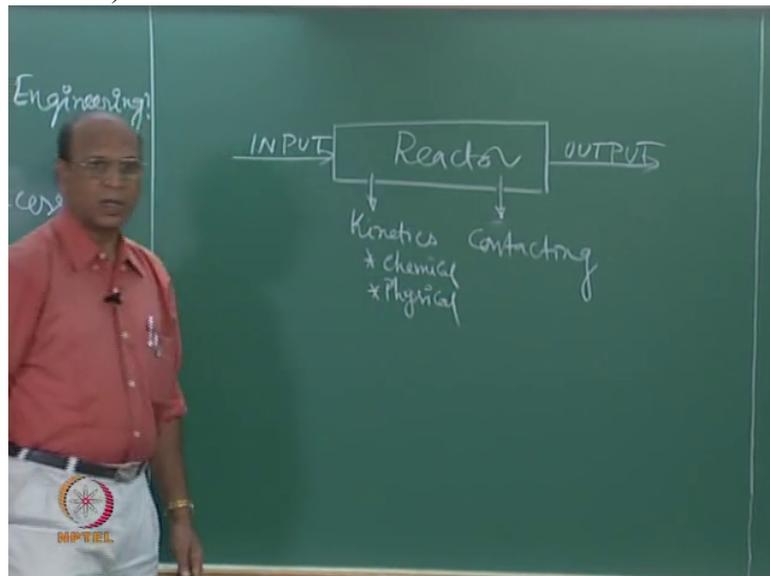
here we have contacting, yeah. Some more

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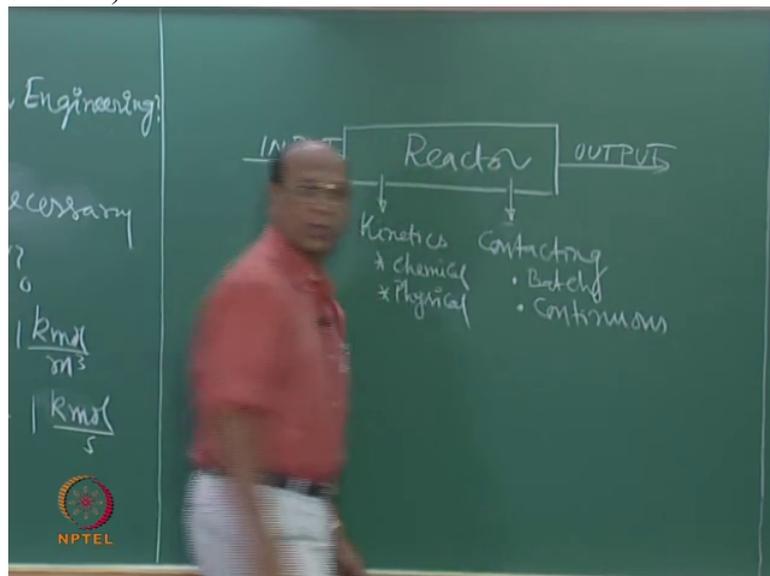
things are in here, in kinetics we will say here chemical and physical, physical

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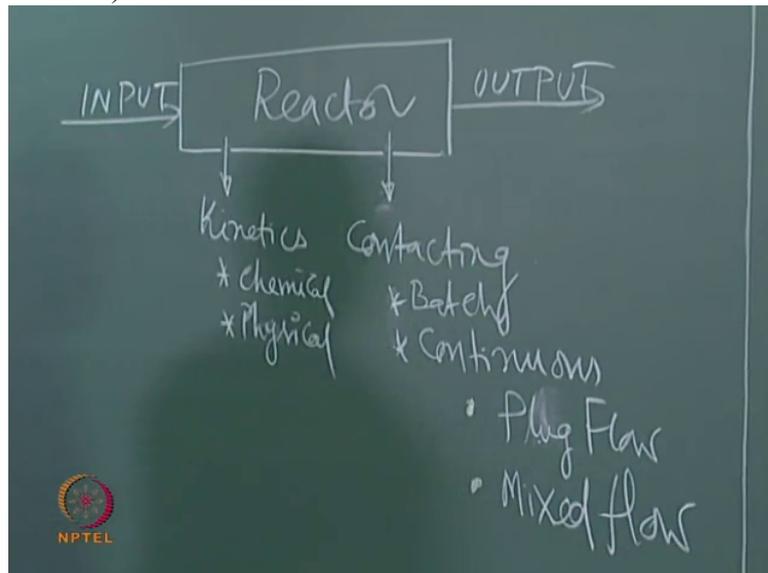
and in contacting you have batch, you have continuous.

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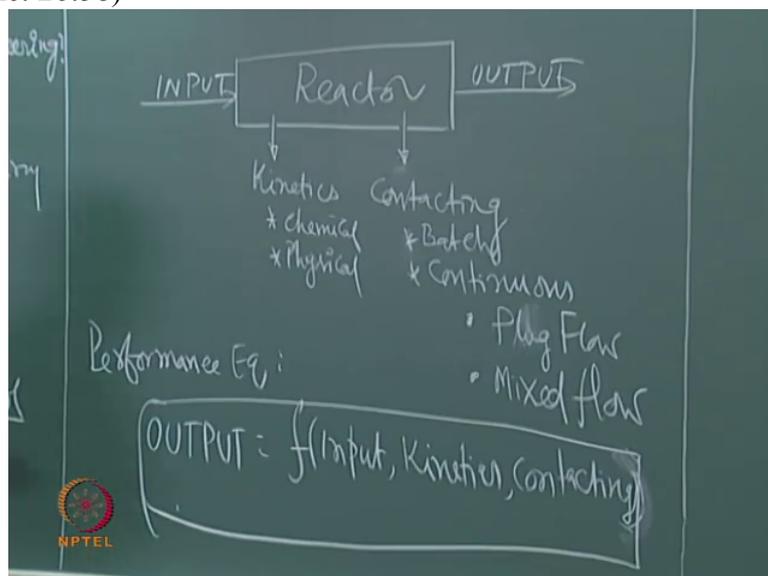
And in continuous again you have, yeah not semi-continuous I think you know, yeah, we have here, maintain the same thing, Ok, here I have, I hope you understand this P F is plug flow or I think first time I have to write because others also are there, plug flow, and mixed flow.

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So now entire thing also we can imagine as a performance equation, performance equation, it is a design equation indirectly; its output is a function of input, kinetics and contacting. Ok. This is a function and this is the performance equation, this bracket, Ok. Yeah this output

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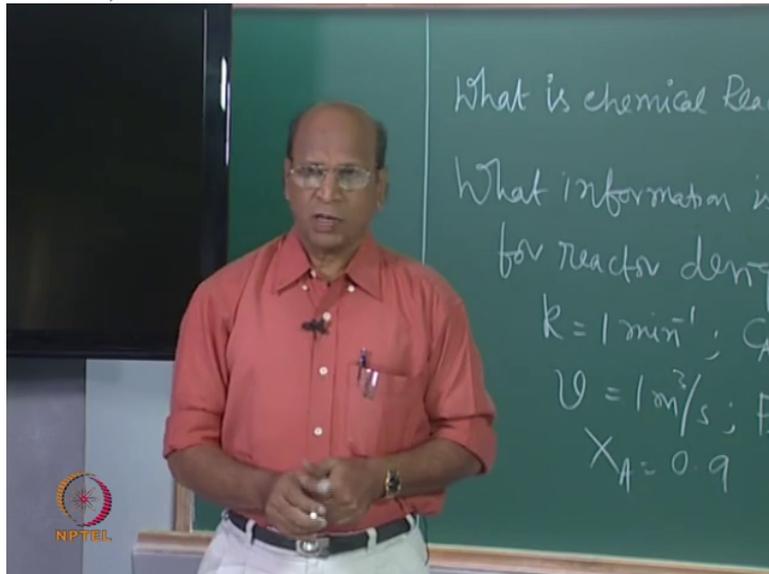


means what do you get from this equation? I mean, this output means what parameter you are expected to calculate if that is an equation?

(Professor – student conversation starts)

Student: Conversion

(Refer Slide Time: 27:15)



Professor: Conversion

Student: Volume of the reactor

Student: Volume of the reactor

Professor: Volume of the reactor, which one is right or both are right?

Student: Both are right.

Professor: Both you have to calculate?

Student: No Sir, any one you can calculate.

Professor: Yeah given

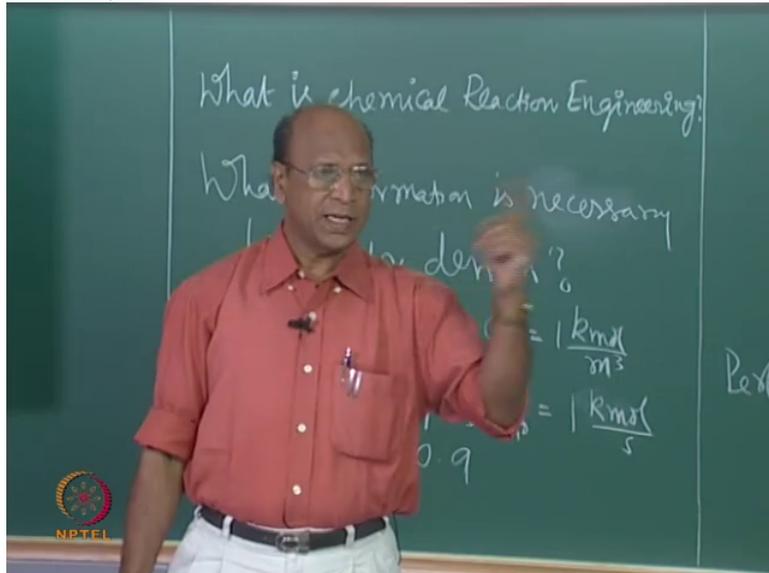
Student: Given one, you can calculate

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Professor: Always the problem in chemical engineering is, that given the volume,

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find the conversion. Given the conversion...

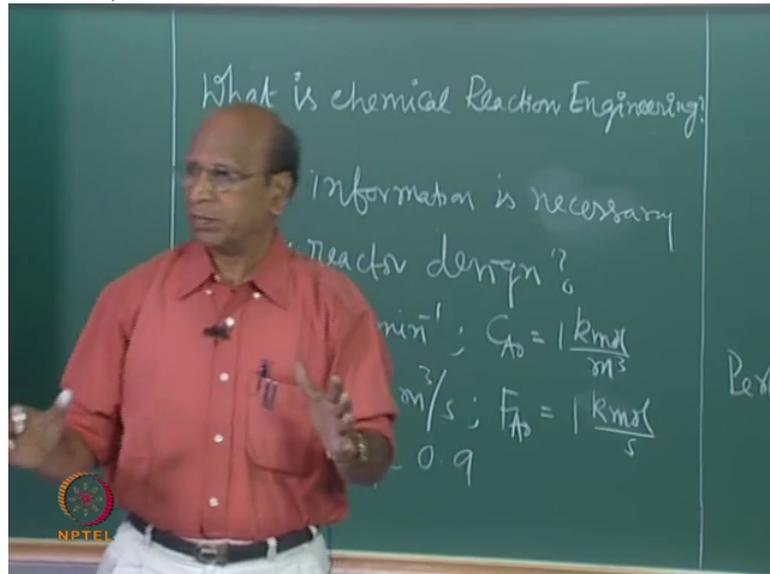
Student: Find the volume

(Refer Slide Time: 27:42)



Professor: Find the volume. Whenever you are designing a new

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reactor, because reactor volume you do not know. That is why you have to always assume that what is the conversion.

(Professor – student conversation ends)

No one tells you what is the right amount of conversion, Ok. And ambitiously speaking all of us want 100 percent conversion. But if you go to 100 percent conversion the volume of the reactor will be infinity. It occupies the whole universe. We do not have space to go and operate. You should be inside the reactor, Ok, yeah.

So that is the reason why you have to assume some conversion, economically viable conversion. Otherwise you know from 90 percent conversion, 95 percent conversion, 99 percent conversion the value will, the value of volume will tremendously change. When you derive the equation, when you calculate you will know. So from point 9 9 to point 9 9 5, tremendous, exponential increase, Ok. Very steep increase. So volume will become infinity when you go to point 9 9 9 9, that.

That is the reason why economically viable conversion which only you know. As engineer you have to have that feeling that, Ok beyond this. Nowadays of course with computers we can simulate with point 9 9 9 9 9 and then point 9 9 9 9, point 9 9 9, point 9 like that. Ok then you will have what will be the total volumes you are getting.

So depending on those volumes you can choose what is economically viable. Why economically viable means if the volume is infinity and you have to bring the material which is already available in the whole universe and then try to design. The volume itself is infinity, Ok, so materials of construction is required. And how do you supply heat? How do you remove heat? All this things is a problem. So that is why, economically viable.

In all these definitions, always that economics is coming for engineering, Ok. That is why, another simple example I will tell you to make you remember. That as a scientist I do not have worry about economics, right?

One example is, let me say this that I have invented a small pill, Ok, tablet and if I take that tablet, lifelong I do not have to take any food. Because that gives you sufficient amount of nutrition, energy to the body. Nutrition, energy everything to the body. But the only problem is the cost of this tablet may be one billion dollars. Ok. Scientist can say that. Cost of my tablet is only one billion dollars. Ok. You cannot find out any fault with him.

But as an engineer, if you are able to produce that one for 1 paisa, then there is no chemical engineering, there is no electrical engineering, because who will....and after all we are all working only for our food and life. The moment you have that food, very happy, that one paisa somehow you get it and lifelong you do not have to eat and then you can always happily jump and dance and all that. You know this place will become really paradise. You know paradise what they do most of the time? Yeah, Dhania what do they do?

(Professor – student conversation starts)

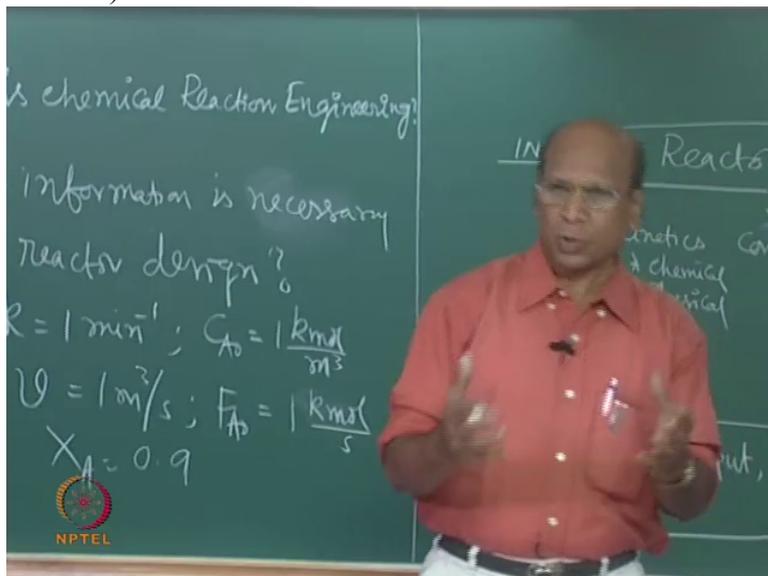
Student: (laugh)

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Professor: In paradise at least

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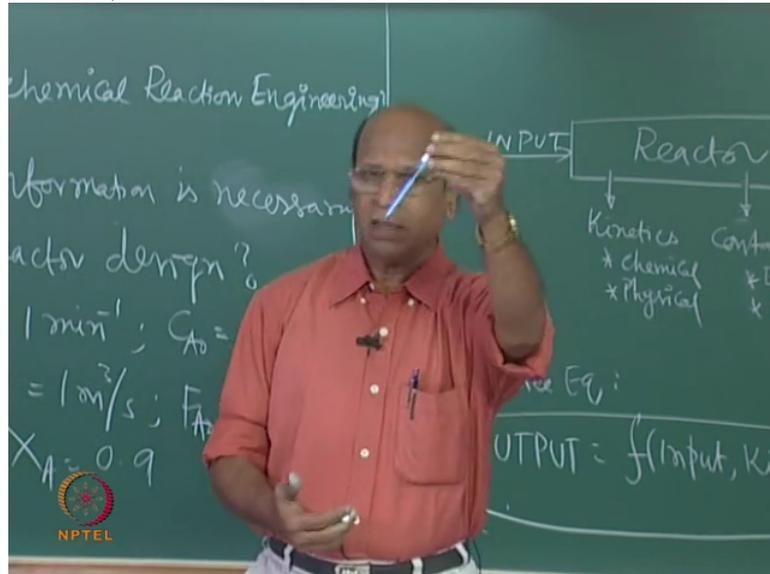
the stories tell us that there are four beautiful girls. Who? Rambha, Urvashi, Menaka, Tilottama. Always they will be dancing. Others will be always watching them, that is all.

(Professor – student conversation ends)

That is what they do in paradise. So our place will also become paradise. Ok. So we will have many Rambhas here. They have only one Rambha. We have many, many here, beautiful people on this planet. Ok. So that is why.

You know, that is the difference between a scientist and an engineer. Always when engineer is making product, it should be as economically viable and also it should be affordable by the people who have to buy those products. Otherwise what is the point in, you know, making this wonderful pen

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with nice plastic and all that, and then say that this is again 1 billion dollar.

Who will buy? 1 billion dollar, I think even Ambanis they do not have, Tatas do not have. 1 billion they have? They have? I am old generation guy where I think, our dosas used to cost only 10 paisa or 15 paisa, Ok, dosa, or idli may be only 5 paisa. So that is the generation which we belong. The moment you put more zeros, I think our mind will not work. Billion has many zeros. If you ask me, Sir billion how many zeroes? I do not know. I know how many zeroes 10 has, only one. That is all. Ok, anyway.

This is the information and you know, yeah this is economically viable thing is very, very important and in all engineering, irrespective of chemical engineering, every engineer should feel that, yes he has to produce anything whatever he is producing. If he is constructing the house as civil engineer, then again it cannot be costing; you know millions or billions of dollars.

If he is able to make small houses for everyone, excellent engineer. And for that again, civil engineers alone cannot live. Because chemical engineers have to be there. Why? They have to supply cement. Correct, no? Yeah and inside the furniture also.

I mean wood we are not making but I think that beautiful paintings for wood, varnish for wood, carpets all this material, yeah Fevicol too...if they do not have Fevicol they can use nails. Earlier they were using only nails nicely, because on this planet even iron is not available so that is why we have gone for Fevicol, yeah. You were telling something?

(Professor – student conversation starts)

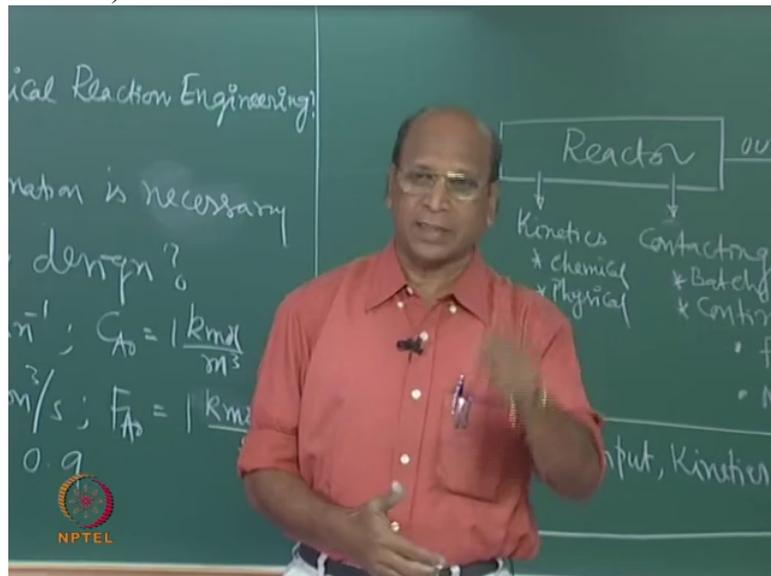
Student: That, for nails also we need blast furnace.

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Professor: Yes, blast furnace we need. Blast furnace again the technology

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there is chemical engineering because that is gas solid non-catalytic reaction, Ok. This iron is converted, iron ore is converted to iron, right, yeah that also we will discuss in the next class and yeah in the next course.

(Professor – student conversation ends)

Yeah, that is why, yeah, even electronics engineer, if you produce TV for may be again for billions of dollars who will buy? But that is why now the TVs and all that, I think it is electronics which, where the cost of electronics components are every time decreasing, decreasing, decreasing. That is the only thing. All other costs are increasing, increasing, increasing. Ok.

You can see earlier what is the pen drive and now what is the cost, earlier what is the cost of C D, now what is the cost of C D, I think I was surprised, sometimes back, my students were telling even for 7 Rupees, 3 Rupees, for 7 Rupees you get the C D. And I was remembering it is 120 Rupees when I purchased long time. Ok, now I only take from others (laugh). Ok. Yeah, so that is the kind of thing.

And like that, in every engineering, if you are able to produce goods cheaper and cheaper, this planet will be really paradise, Ok and even producing not only materialistic things, even for food. Even now we do not have much food. Many people are there without food.

If you are able to produce that food, you know excellent fertilizers where immediately, before putting the fertilizers itself the crop should come. If it smells, Ok (laugh). The moment you show the smell for the plants, if they are growing so happily, then why not? Just I think, you know have lots of smell and then just breeze over the, you know, the fields. Then automatically you will get very beautiful fruits and then all wheat, rice and all that, then the entire planet will be so beautiful.

But you know for human mind nothing is impossible. That is why I like science fiction movies. I was telling you no. Because there their mind you know, how beautifully it has imagined! Particularly that Avatar movie. Entire planet was in the minds of James Cameron. You know, he is the director, he was the director, he is the director.

Entire planet, right and also how he imagined the people. What should be their height? What should be their color? And you know everything. Sorry? Floating mountains. It is a new concept, floating mountains. I do not know floating mountains are really floating because wind stream difference and all that is there, anything that is floating; having more than density of air it should fall. So that air should be very, very thick I think very dense air.

Otherwise you know, they cannot float no. Otherwise the mountain should be like carton. You know mountain, you know there are big trees also on those mountains. Right and all that imagination and I think the best imagination in that movie which I liked is putting that pigtail to, yeah when they are riding the birds or horse, that concept is so beautiful concept because we can all see. Ok. You have to go today and then put your pig tails to C R E book, Levenspiel book. Then everything, you will be part of that.

You know concept is so beautiful! And in our old scriptures this is there already. Whatever you do, you have to be part of that, whatever you do. So that means that he is now physically showing you how to become part of that that is all the difference. We have already, you know, whatever you do you have to complete immerse in that. When you do that I think, Dnyaneshwar is one of the wonderful names.

The moment you close your eyes and meditate you will be automatically dissolving in whatever you do. In whatever you do. The moment you are preparing for a C R E exam, close

your eyes the entire C R E book should be before you, each page, page by page. Then you are automatically part of it because you are seeing by closing your eyes that book in your mind.

You know, I told you all of us has mental screens. Not mental, mental screens (laugh). All of us are one way or the other mental, that is different (laugh), but all of us have mental screens. So those screens will automatically project what we would like to have if you had familiarity with that. I do not know if I asked in this class or somewhere else.

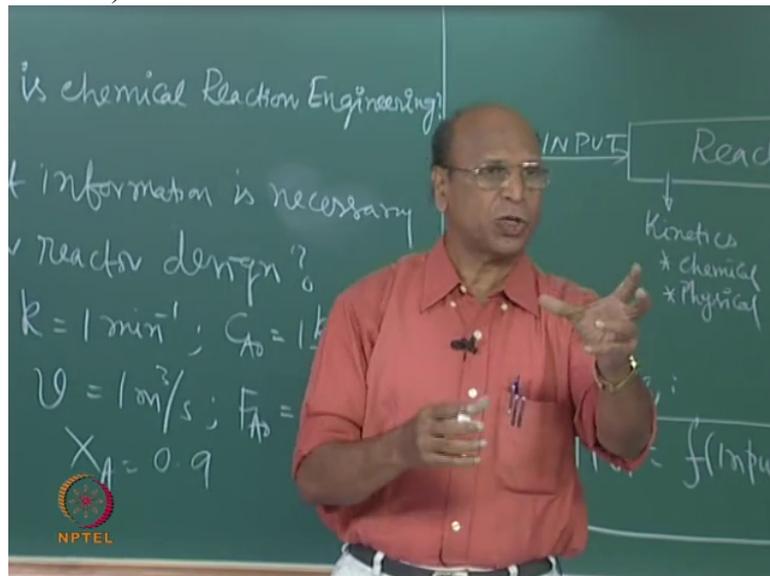
The moment I tell Delhi what do you remember immediately? When I asked you?

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Yeah, that means immediately,

(Refer Slide Time: 38:02)



depending on your exposure someone may imagine, you know, in his brain or in mental screen Qutab Minar. Someone may see that Gateway of India, someone may see Parliament Bhavan. Someone may see Palika Bazaar where they are interested in shopping and all that, Ok.

So that is the kind of mental screen I am talking. And that mental screen can be beautifully used for our, yeah, either C R E or any subject, yeah, for our chemical engineering. That is why I think I have some exercises for the students, you know.

Just go and sit down in your room and then just imagine a heat exchanger and then try to plot the temperature profile. You will never forget the subject if you do that. Imagine a distillation column and then just imagine where is the feed, how the temperatures are varying, from bottom to the top or how the concentrations are varying, that means indirectly what I am asking you is to plot temperature profile and concentration profile, right?

And now you can go to extraction column. In extraction columns, it is a column. There may be mixer settlers also. You know one mixer settler where it mixes and then settles in some other one, all that. So there what kind of concentration and temperature profiles you will have? You just sit down and imagine and try to plot all that in your mind. You will never forget the subject.

It is not the marks which are important. You may be getting S, in I I T Madras we have S, 10 out of 10, in some other places it may be A, A may be 10 out of 10, it may be 100 out of 100. You know, some many universities also are still giving the, actual marks, absolute marks. So when you have 100 out of 100 on the paper, does not mean you have 100 out of 100 knowledge in that subject.

But when you do the way I am telling you, just imagine and try to plot in that subject whatever things you have gone through, you will never forget the subject and always subject is with you and marks are in your cupboard, correct no? You take marksheet and then you cannot carry every day. So you just put somewhere else. But whereas this brain you cannot keep anywhere. Ok, it has to come with you wherever you go.

So then I think you will beautifully understand whatever is happening in the subject. That is what is the interest you have to develop I say. Everything is interest that is all. And most of us are skeptical. Ah chemical engineering, so what? Distillation, so what? Reaction engineering, so what? So what is very bad word like cracking the exam? Ok. Either we have so what or cracking the exam. That is why simply we are indifferent for the subject.

And every subject is a wonderful subject I tell you. I have shown you what is the beautiful amount of science that is there even in brick technology, bullock carts, anything you see in nature what is made by us, made by nature is also wonderful. So that is why we understand nature first and then try to mimic in our things.

Most of the things what we produce like flying aeroplanes, yeah, only birds. You know our Gods used, you know that Garuthmantha, it goes and, we also had what is called Pushpak Viman, right Pushpak, yeah. So all that were there in mythology, may be they were imagining, I do not know whether at that time, they were really existing, or is their imagination? Because when people write the stories, beautifully they can write.

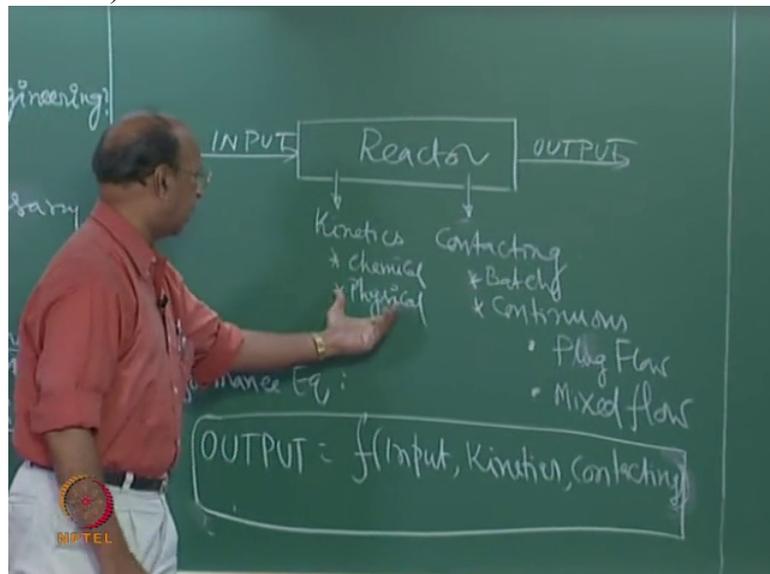
Again science fiction at that time. If there was science fiction at that time you would have created in the mind that this is Pushpak where people can travel at that time. We did not know that, right? Because nowhere to go back and only science fiction it is possible to go back into the past and also to go back into the future. But right now we are not able to do that. May be

it may come after some time, we do not know. If you are able to do that then probably you will get.

So that is why I think you know this chemical reaction engineering, definition on your own you can now create provided you do all that what I have told you, that imagination, thinking about these examples then afterwards when you ask this question, this is the one for the entire, I mean teach you 10 reaction engineering courses, I can never come out of this diagram.

And if you also understand the meaning of this diagram,

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what do you mean by physical kinetics, what do you mean by chemical kinetics, what do you mean by contacting, Ok and what do you mean by batch, continuous, in continuous again you have two types of ideal reactors, actually that is ideal contacting, because you can have non-ideal contacting but you will have lot of varieties. But ideal contacting, this is a wonderful information for reaction design. I thank really Levenspiel for this, you know.

Everything, whatever it may have heterogeneous reactions, homogenous reactions everything you may have but still you cannot go out of this, I mean out of this diagram, out of this performance equation. Who gives input to us? I have already told you. What do you mean by input?

(Professor – student conversation starts)

Student: Reactants

Professor: Input is not given by chemist.

Student: Raw material

Professor: Yeah, how do you get how much raw material is required?

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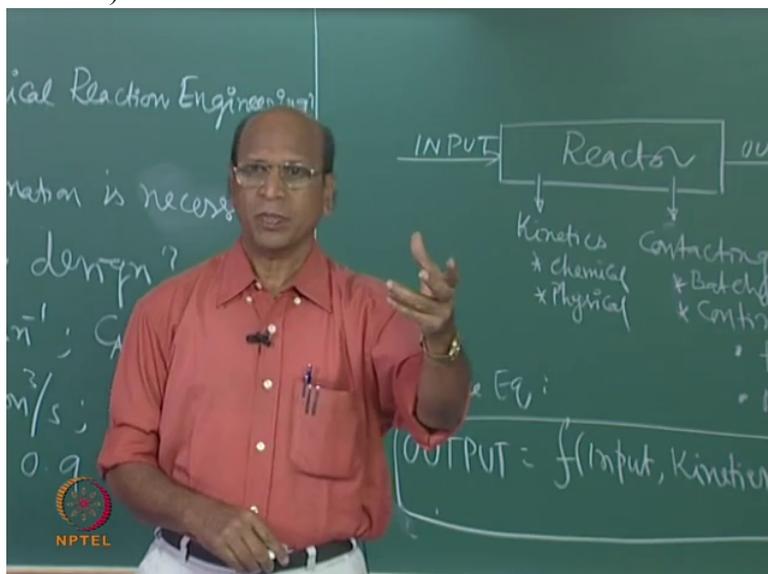


Student: Products

Student: Based on products.

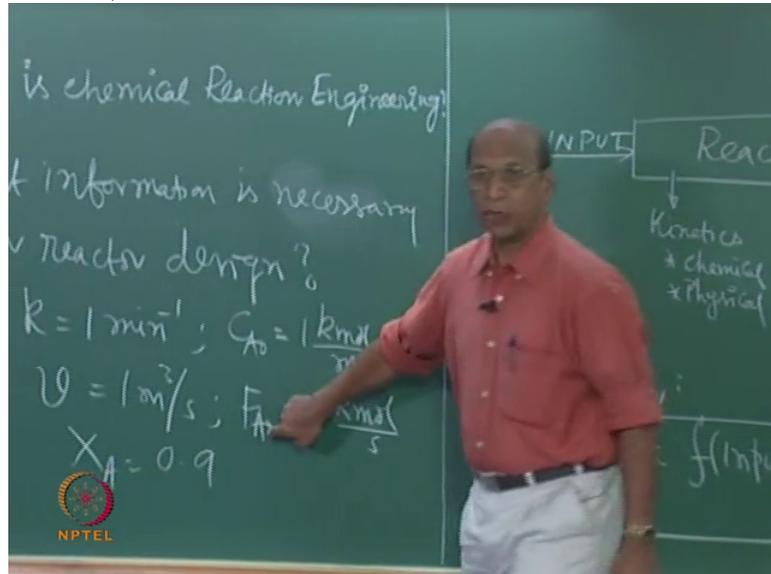
Professor: Products. From product you have to back-calculate and then say that some, she was telling me that I think we need the flow rates, right. How much you have to produce?

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Ok. That how much you have to produce is input. That is in Levenspiel language F A naught, F A naught, moles per second, not volumetric flow rate, molar flow rate, that is what this one,

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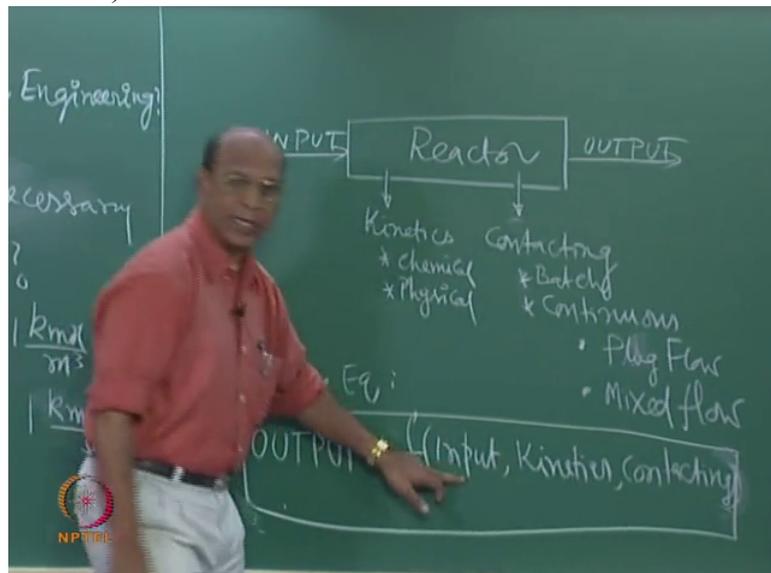


F A naught. F A naught, already you have with you.

(Professor – student conversation ends)

Because someone went to market...because you know this product has demand, someone went to market and they found out that this is the total demand in a year, so that is your plant capacity, that is your F A naught. When you convert that product into reactant through stoichiometric equation, Ok. That is one parameter. This already we know,

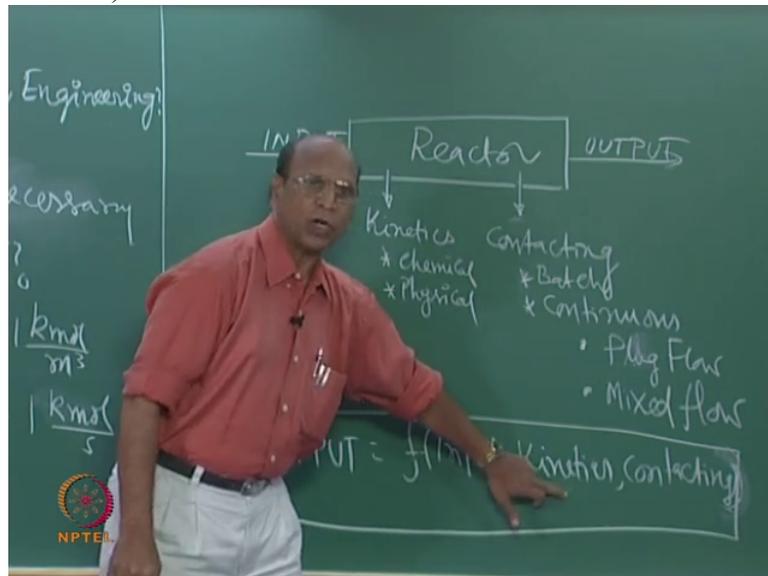
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Ok.

Then next one is kinetics. From kinetics what

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do you get? Simply minus  $R_A$ , right? Order of reaction, all the type you know, every reaction need have order, first of all. So kinetics will tell you what is rate minus  $R_A$  as an expression. It may be  $K$  into  $C_A$  if it is first order, simple expression. Or it may be very complicated with so many terms, in the numerator, in the denominator, everywhere, Ok.

So that means we have to now understand for my reaction where I have this stoichiometry, what kind of kinetic expression I get. That is what this, there I have to work. Here I do not have to work much. Why? Because it is market survey. Simply I will go to market and then take the statistics and say then so much demand. We do not have much work there. And here I have tremendous amount of work. In fact this is the most difficult step in chemical engineering. In chemical engineering itself I think.

Then what is this one, next one? Next one is what type of reactor you are going to use? That is all what you have. If you know what type of reactor, let me say batch reactor you have, batch system, right and then I know kinetics, I know the input, how much I have to put there, right, then what is that I have to calculate now?

If I want to design reactor then I should assume also conversion and then fourth, the volume can be calculated. Or if I am already having a reactor, and I put all these, I have a batch

reactor, I know kinetics, I know how much I have to dump into that, because contacting is batch reactor, so then this will be conversion. Because volume I know already. That will be conversion, Ok.

So that is why either you have to assume conversion or you have to assume, yeah volume. And always for a new process, new process, it is only volume I have to calculate. For an existing reactor already, an old process, there is already a reactor, now I can only calculate what is the maximum conversion I can get from the, from that volume. That is all.

Throughout, not only in chemi/chemical, you know in reaction engineering, everywhere it is same. What are you doing in distillation? You are first assuming 99 percent purity, then calculating number of stages. If you know number of stages what do you calculate?

(Professor – student conversation starts)

Student: 0:46:22.1

Professor: Because that problem is never thought normally.

(Professor – student conversation ends)

If I give you I have 10 plates and if I also give you composition there is no problem. You do not have to do anything. But always what we give is, either give number of plates and then ask you to calculate what is the composition you get and also the flow rates and all that you know, you get by material balance. Or give you the extreme compositions and ask you to find out how many stages required for that.

Heat exchange? If I give you the temperatures, you calculate area. If I give you area, you have to calculate temperatures. And if I give you area plus temperatures you do not have any problem. But I think even if I give in the examination, you may try to calculate. Because your idea is, oh there must be some trick. So let me calculate. (laugh) You never write simply that everything is given; I do not have to do anything.

In fact that kind of questions I will give.

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Chemical Reaction Engineering

Information is necessary

Reactor design?

$\text{min}^{-1}; C_{A0} = 1 \text{ kmol/m}^3$

$v = 1 \text{ m}^3/\text{s}; F_{A0} =$

$A = 0.9$

INPUT → Reactor

Kinetics  
\* Chemical  
\* Physical

Contact  
\* Bed  
\* Con

NPTEL

Prof. K. Krishnaiah  
Dept. of Chemical Engineering

Ok (laugh) Because you should know what is wrong, what is right. It is not that every problem you have to solve. So that is why, be careful in my question paper. That is the kind of, everything might be there. You do not have to do anything. If you write that nothing to be done, you will get the marks for that. Because I think that is a great information for me. Because you are able to identify everything is there.