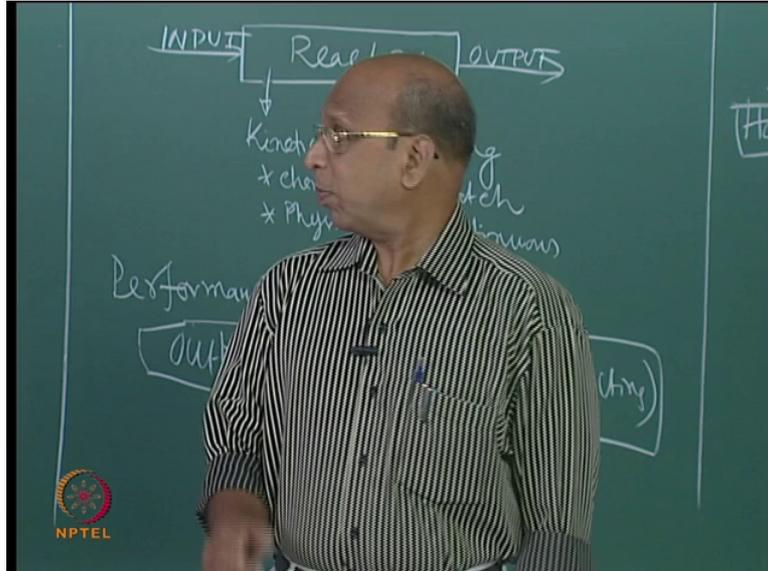**Chemical Reaction Engineering 1 (Homogeneous Reactors)**
Professor R. Krishnaiah
Department of Chemical Engineering
Indian Institute of Technology Madras
Lecture No 08
Homogeneous and Heterogeneous Reactions Part 2

(Refer Slide Time: 00:09)

Actually what is the real difference between homogenous and heterogeneous? When do you call the reaction homogeneous? When do you call the reaction heterogeneous? See the phase difference is L K G answer. Now you have graduated, so I think you know the correct answer you have to tell.
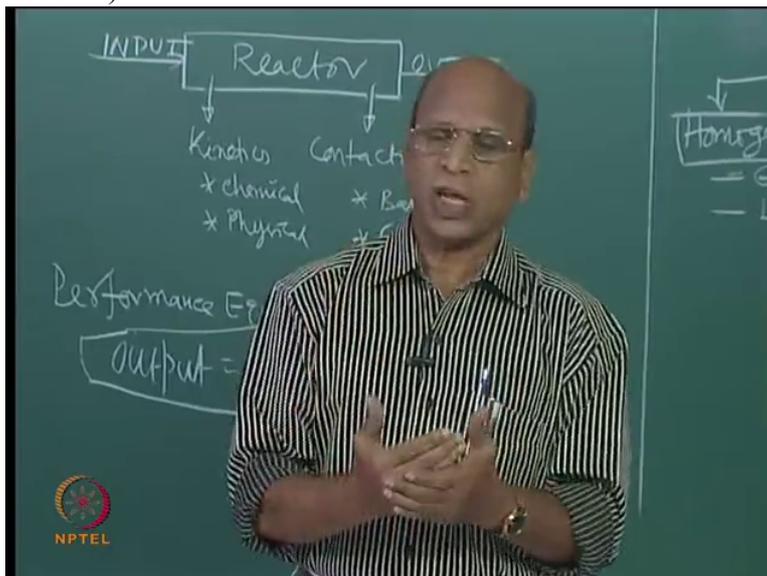
When you tell there is no mass transfer limitation in any phases, then you have the homogenous. That means no, again I told you no, American society, you do not have to see another molecule for getting married. Yeah. Immediately it is available. Right,

you do not have to go other house, search and parents and all that.

But in solids what is really happening? I have 2 solids coming together for reaction. Both are pure. But reaction can automatically take, take place? Why?

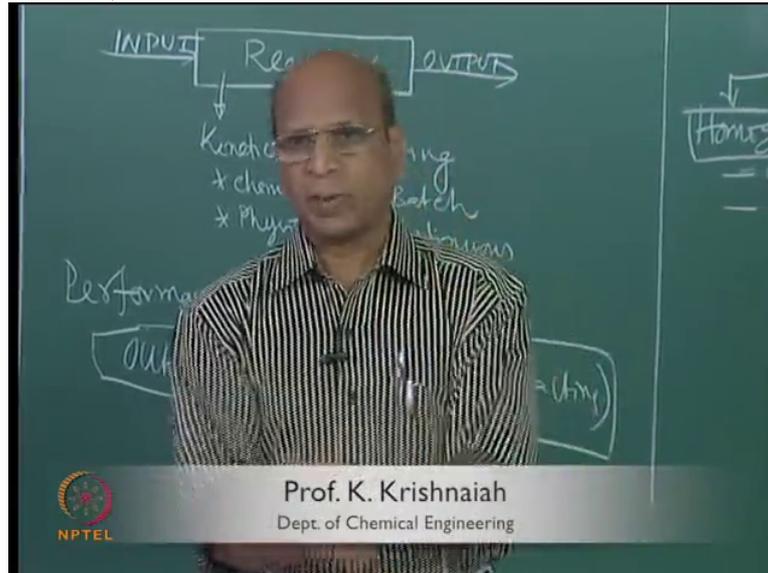(Professor – student conversation starts)

Student: Because chemical 0:00:58.5

Professor: Because those molecules are not movable, right?

(Professor – student conversation ends)

So that is why what you have to do is, you have to break this solid,

Prof. K. Krishnaiah
Dept. of Chemical Engineering

break this solid, make them very fine powder, if possible molecular level, you can never do it. Then you mix them perfectly and then bring to temperatures, high temperatures then the molecules start diffusing a little bit. That is called self-diffusion. Ok

So with that only it will react. That is why solid-solid reactions are very, very slow. Fastest reactions are gas, Ok. So that is why, again please do not tell what is the difference between homogenous and heterogeneous means one phase, two phases. Over. That stage is over. You have to learn something new.

Ok. You can tell that, anyone asking, that if there is, what is the definition of homogenous, if you say that all molecules, I mean whatever number of reactants that are available, if all of them are easily available in one phase, then you have homogenous, Ok.

Heterogeneous, that is not possible, necessarily from one phase to the other phase the molecules have to move, right? So if you have coal and oxygen, by keeping coal in one room and oxygen in one room, you cannot have. Even you have same room but if there is no sufficient temperature, the reaction temperature, still coal may be there, air may be passing over that. Still you do not have reaction.

That means the molecule is not enough for the reaction to take place. Or activation energy whatever you say, right? So that is why you have to bring them to the reaction conditions

environment and then automatically the molecules will move and the reaction takes place. That is the difference now, actual difference.

You want to ask something? No, you, you, blue banian? You only. I am talking about you. No. You said like this,
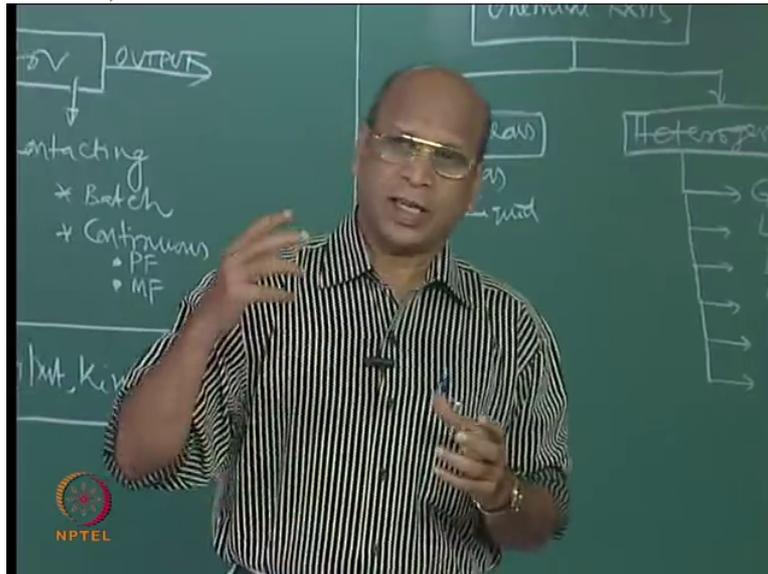
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so I thought you are asking. Yeah, Kalpana?

(Professor – student conversation starts)

Student: Will it remain homogenous throughout the reaction?

Professor: Yeah, it is a good question in fact.

You know, during the reaction if it remains homogenous, we take them as homogenous, right? But immediately when the reaction is taking place, there may be a condition where the products are forming as precipitates, Ok solids like for example. Gas it cannot happen, but may be it may be happening in only in liquid phase. So if that is not affecting your rate of reaction, then you can call that as only homogenous. Ok.

(Professor – student conversation ends)

So in fact, in fact that is the point which I have to also tell, which I have forgotten at that time when I was talking. So now that is a good question where during the reaction, molecules are freely available even though there is a phase change, that means the product when it is formed, automatically it is precipitated. You may be stirring it but I think still you have at molecular level the availability of the molecules for the reaction to take place, Ok.

So that is why you can still take that one as homogenous only, good. So that is what, what we have discussed here with this diagram
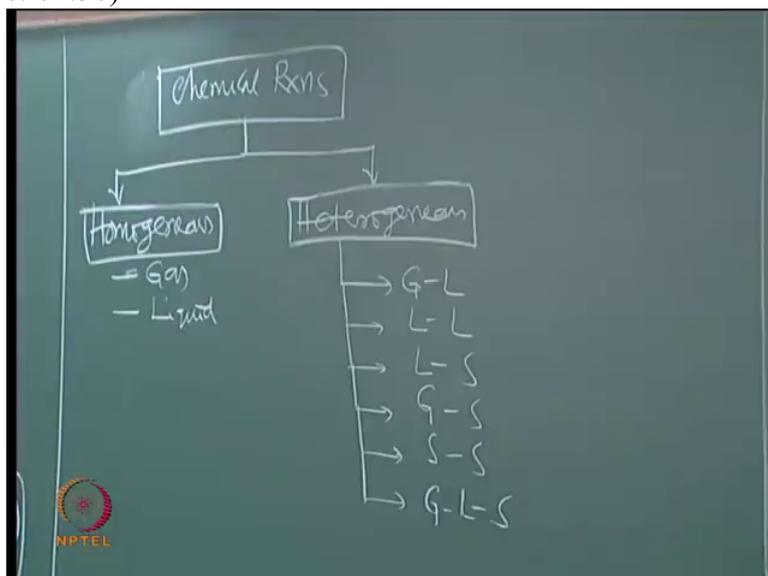
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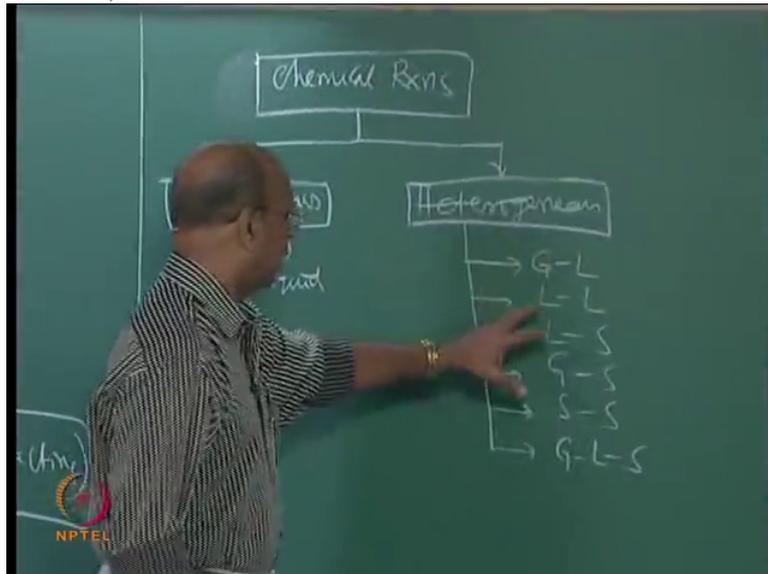
and we have also identified what are called catalytic reactions and non-catalytic reactions. Now we have to identify in gas-liquid mostly what is the kind of reactions you will have. What kind of reactions you will have in gas-liquids?
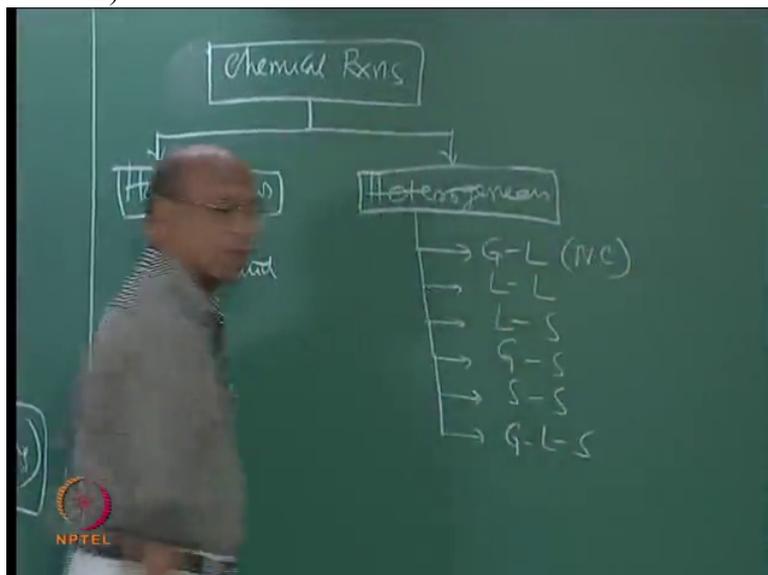
Are they catalytic reactions, or are they non-catalytic reactions? Mostly. There may be one reaction, you know, very peculiar reaction where you have liquid, gas-liquid right the first one, gas-liquid

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so liquid acting as a catalyst or gas acting as a catalyst, is it really possible, generally? So most of the time for gas-liquid,
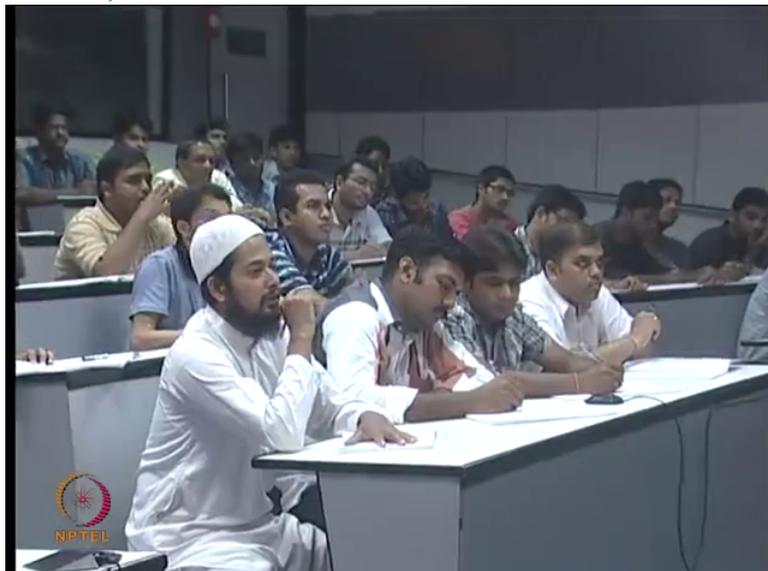
N C, non-catalytic reactions. Right, Ok. So for liquid-liquid?

(Professor – student conversation starts)

Student: No

Professor: You think, I say. You are only just listening to me. You have to also think, you have to question me, you have to think.
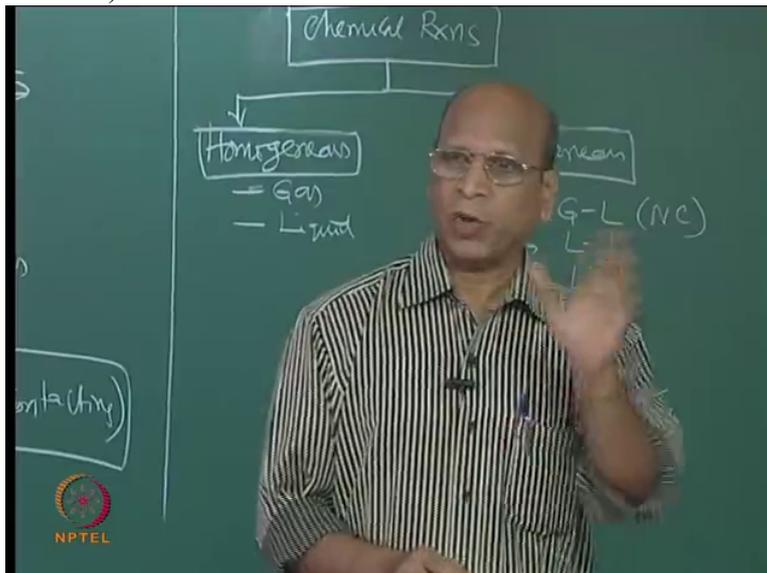
Student: Both possible

Professor: Both possible, good. Answer is right. But why?

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Student: 0:05:07.5

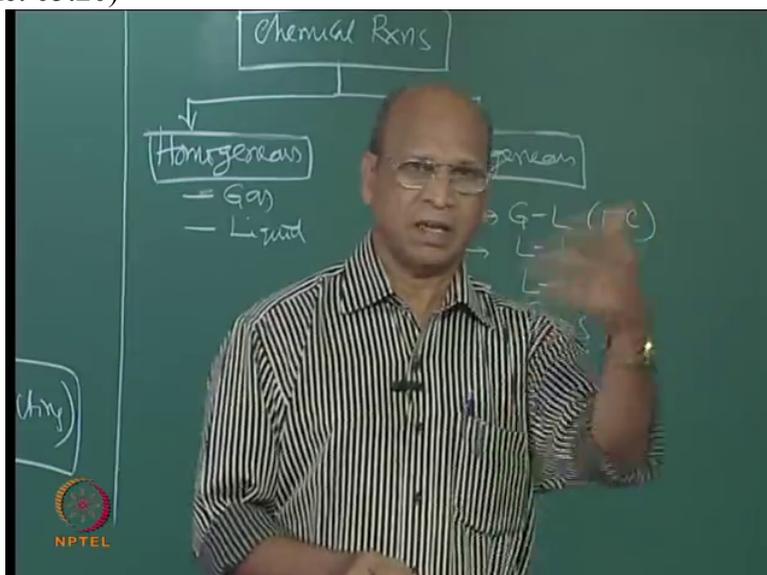Professor: Auto-catalytic is homogenous, can be homogenous.

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Autocatalyst is the product acting as a catalyst.

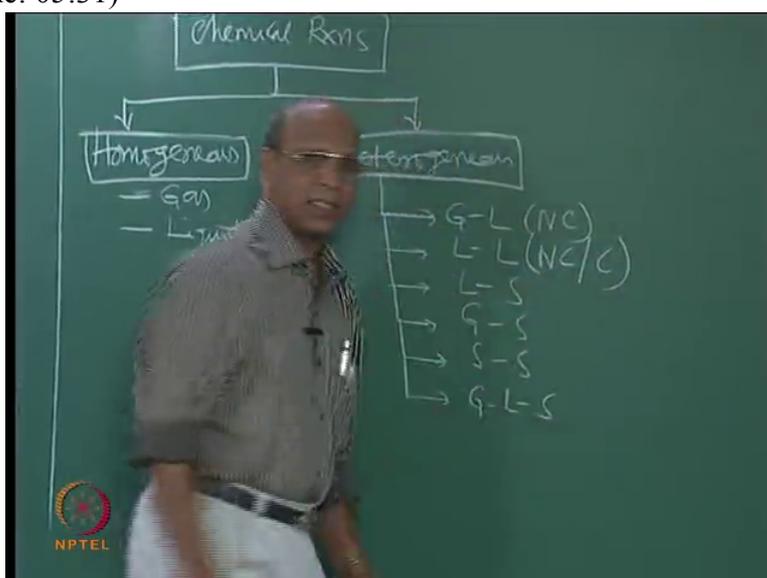(Professor – student conversation ends)

Ok, now we want to use as external

liquid as catalyst, both are liquid, right, so there are many reactions where there are non-catalytic reactions and also catalytic reactions

where one of the liquids can act as catalyst. I think the nitration reactions are like that, Ok. Nitration reactions are like that where, yeah you have to, you know if there is a catalyst, that catalyst in the form of liquid will be, this liquid-liquid, liquid-liquid reaction the moment you put solid here, then it becomes three phases. If the catalyst is in solid form, then you cannot take this. You have to go here.

Now you have three phases, no. Solid. That is why when you are talking about catalyst here, that catalyst must be one liquid but it should be either miscible in this or in this, Ok. Then the

reaction will take place at the interface. And most of the time, and that is why one of the liquid is dispersed into very, very fine solid, droplets, the other liquid is continuously sent and you have to now see in which phase your catalyst must be dispersed, either dispersed phase or continuous phase, right.

That is the conditions for non-catalytical reactions in liquid-liquid. It is possible. Few reactions are there. Then what about liquid-solid?

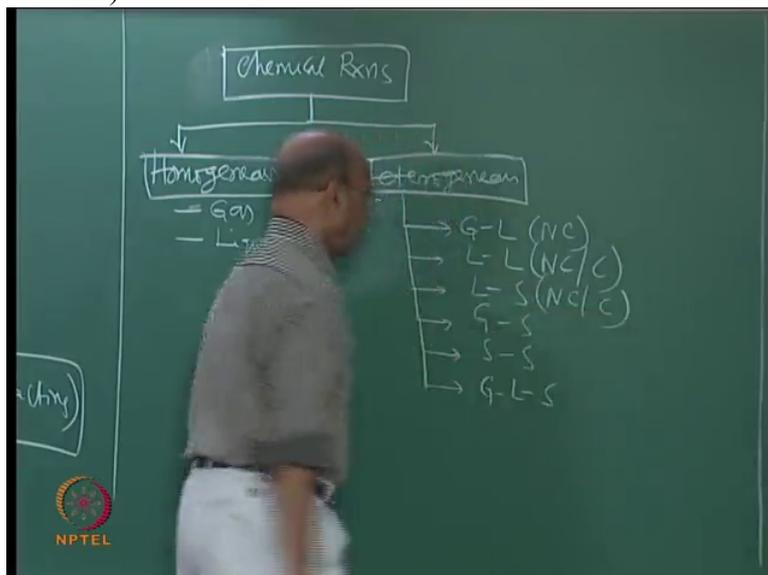(Professor – student conversation starts)
Student: 0:06:49.5
Professor: Yeah,

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liquid-solid, most of the time, where is my liquid-solid, gas-liquid, yeah liquid-solid can be

non-catalytic or catalytic. Because for example, that solid can be a catalyst, over that you send liquid but now this is one liquid, so that liquid is, you know, the reaction is taking place on the surface of the catalyst or inside the particle. So that is possible.

So you have few reactions which can be liquid-solid, either catalytic or non-catalytic. Ok, next one, gas-solid. Most of the things are catalytic and also of course,
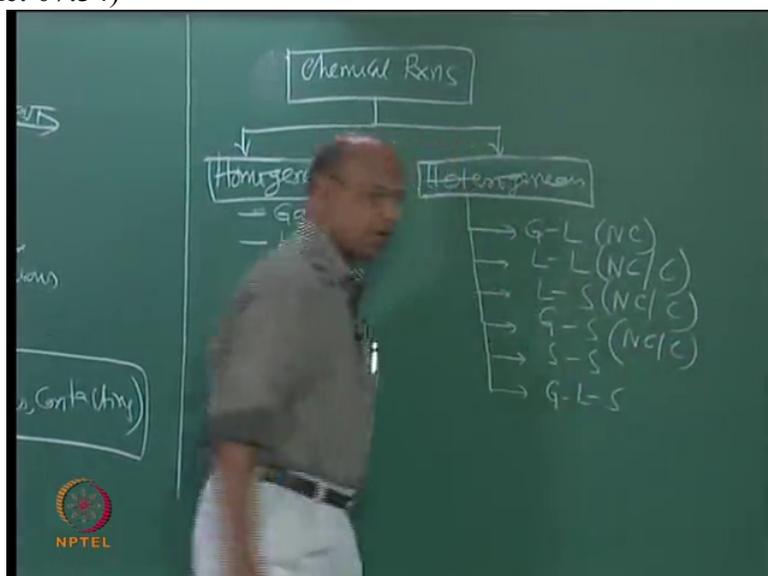
non-catalytic reaction. Give me one example of gas-solid non-catalytic reaction which I have told also just now?

Student: Rusting

Student: Combustion

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Professor: Carbon burning

Student: Carbon burning

Professor: Combustion I think you know
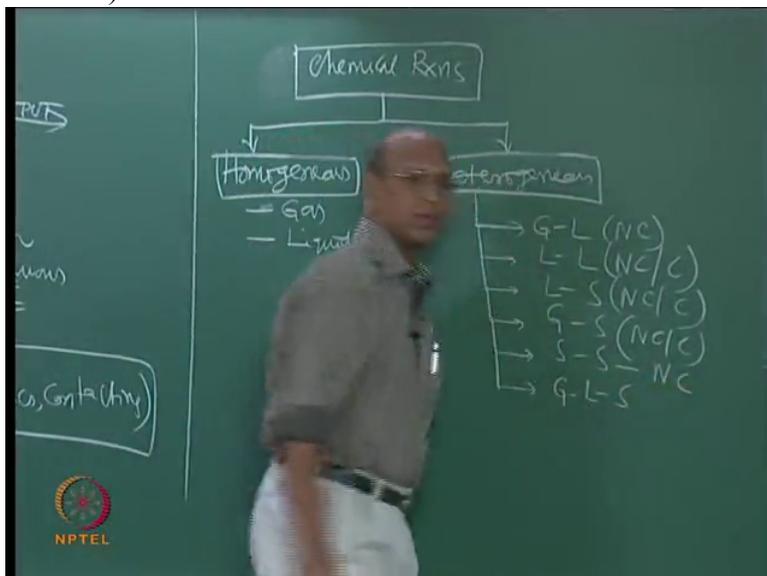
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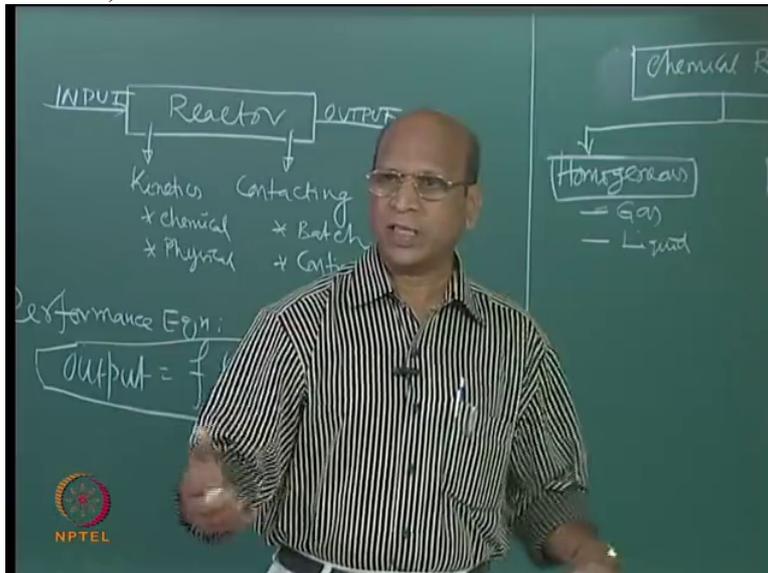
that is very easy for imagination no, so carbon burning. Even rusting is not that easy to imagine. Again your mind has to go to cycle and all that. But here carbon means burning immediately comes to our mind. Because all of us, thousands of time seen this burning. So that is the reason.

(Professor – student conversation ends)

And many people would have not seen, the rusting, rusted cycle. Ok so that is why, that it takes time. Solid-solid? Most of the time it is non-catalytic.

Solid-solid? I mean how do you get one solid catalyst, another solid only but how do you make it? How the reaction can take place? Impossible. And you know can you give one example for solid-solid reaction which you see everyday almost

if you take coffee? That product you use because of the solid-solid reaction.

(Professor – student conversation starts)

Student: 0:08:46.5

Professor: Chinese are very famous for that. Chinese are very, very famous. I have given you so many clues, I say.

Student: Coffee

Professor: What is that? Roasting of what?

Student: Coffee beans

Professor: No, no, it is not, I am not talking about coffee. (laugh). When you are taking coffee, you use this product. And I gave the clue, beautiful clue, Chinese. Chinese are famous for what?

Student: Chow mien

Student: Paper

Professor: What is that? Chow mien?

Student: Chow mien

Professor: Chow mien.

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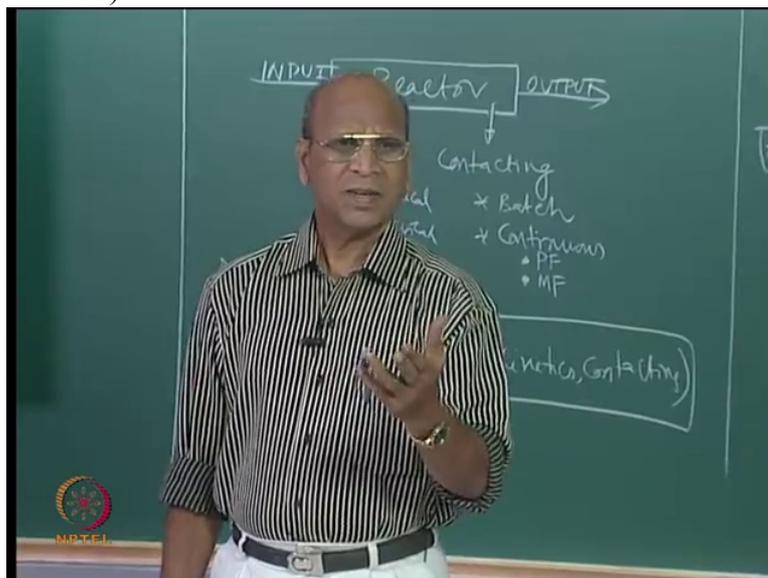
You see, because you are interested in junk food, you remember only noodles.

Student: (laugh)

Professor: And noodles are kept where? In a plate. What is that...?

Student: Ceramics

Professor: Ceramics. Ceramics and glass, Chinese are, long time they have developed the technology.

(Professor – student conversation ends)

The best ceramics in the world available only in China, and you know how do they do it? Solid-solid reaction. And solid-solid reaction has not come to the level of gas-liquid reaction or gas-solid reactions or liquid-liquid reactions because they are very difficult to study. Ok, so that is why, I think this is one of the very, very difficult reactions, very slow reactions and you need, I think you know China, they take that one as an art, the ceramics.

It is not only simply they are producing the plates, they have produced that plates with beautiful designs, you know paintings on that. You can just imagine how they are doing it. And lifelong it will be there. Unless you break it, Ok, so the painting will never go, the glossiness will never go. It is wonderful. Right.

You would have seen no, many movies of Jackie Chan where fighting will be only how to save one jar. That villain will come and hit, and he will jump and then catch and again that fellow will come and hit and this fellow will go and then catch the jar, you have not seen, Abdul? Seen no.

You also see movies (laugh). Yeah because I appreciate the Chinese, you know jars, not Jackie Chan, Ok (laugh). You appreciate Jackie Chan and also try to see what is that he is trying to hold there. In many movies you know he will never allow others to break Chinese treasure. That is Chinese treasure, really. Ok. So that is the one.

And gas-liquid-solid? Can be both catalytic and non-catalytic, Ok. I think mainly it is catalytic when compared to even non-catalytic, Ok. This is again technological interruptions,
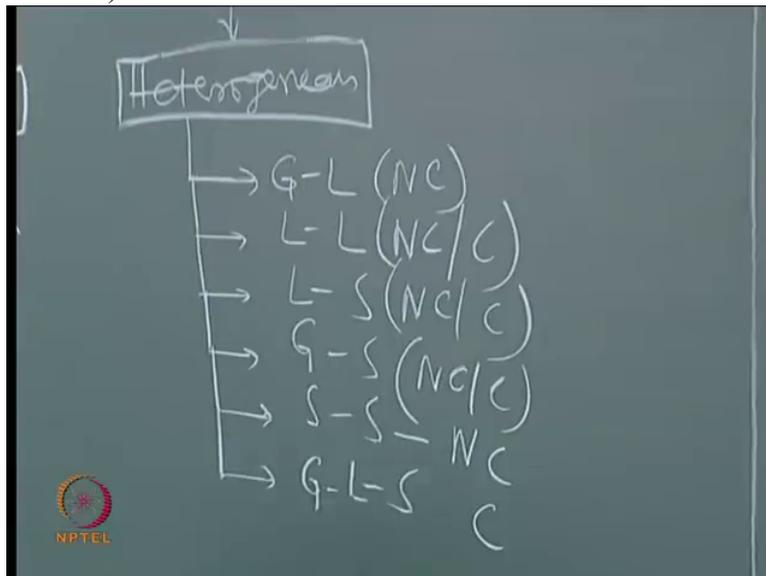
yeah. We have to put bracket here. This also is very important for us. Then we should know that as I told you the design of non-catalytic reactor and design of catalytic reactor will be totally different. So that is the reason, Ok.

So now next one, because you have so many possibilities and the rate of reaction when you are expressing for homogenous, it is very, very easy, right. So normally we write, for an ith component, because you can replace this one by A, Ok, equal to, normally I will also write the equation v i, sorry v d N i by d t,
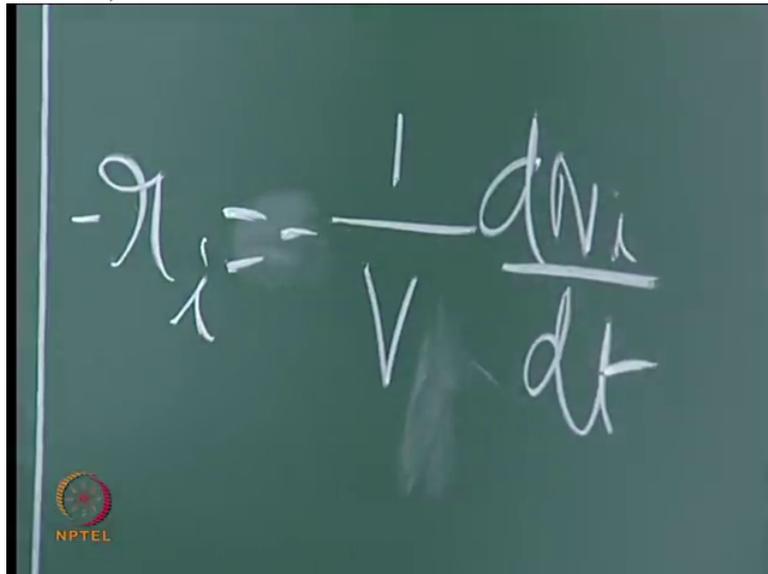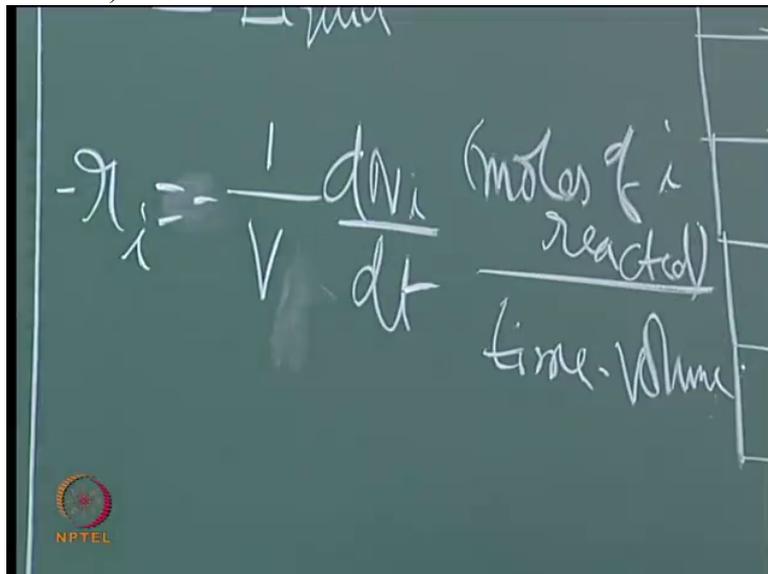
yeah Ok, d N i by d t

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equal to, I am writing in terms of moles, moles of i, of course, if I do not put here, it is formed, but because negative I am putting it is reacted per unit time per unit volume. That is the definition. Ok

(Refer Slide Time: 12:46)

Similarly we can now write for all other things that are possible. I told you this is the simplest one. This is the simplest one because volume means here we are talking about volume of the reaction mixture, Ok. Normally we do not waste our reactor volume, so that is why when we calculate we also think that that is the reactor volume. Actually it is the reaction mixture, right.

If you are conducting slightly at high temperatures and if there is some vapor coming and all that, so that is why you will again allow some kind of vapor space above the liquid, Ok. That is all engineering judgment, how much you have to leave only depends on the temperature, how much vapor is produced, what is the vapor pressure and all that, Ok.

But what we are talking here with volume is volume of the reaction mixture, Ok. So now when I go to different things now, let me take, very widely used is gas-solid,

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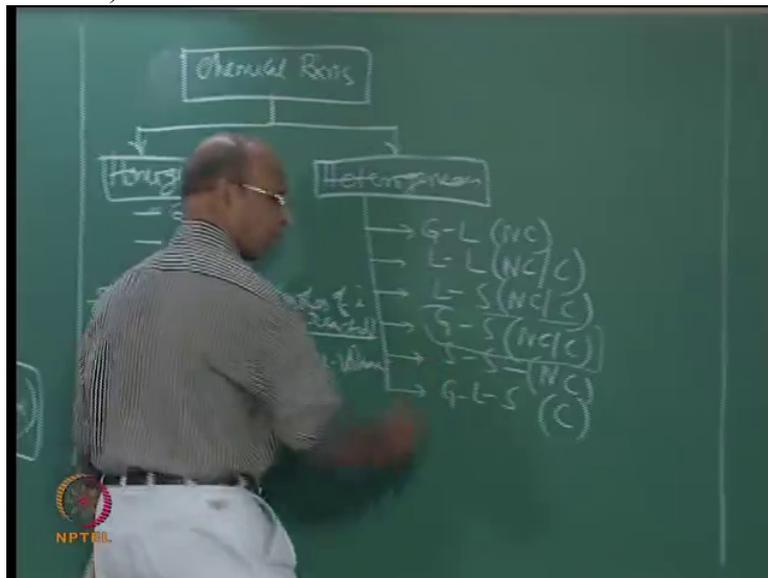
Ok. Gas solid is very, very, so many reactions are there in the industry, some of them can be catalytic, some of them can be non-catalytic, so now we will use that one for, you know, deriving, writing some equations.

That is homogenous, this is heterogeneous, so many possibilities are there. So now based on, based on volume of voids, you have to be very clear, in the reactor, Ok so if I write here again i, yeah, so moles of i converted or, Ok per unit volume per time,

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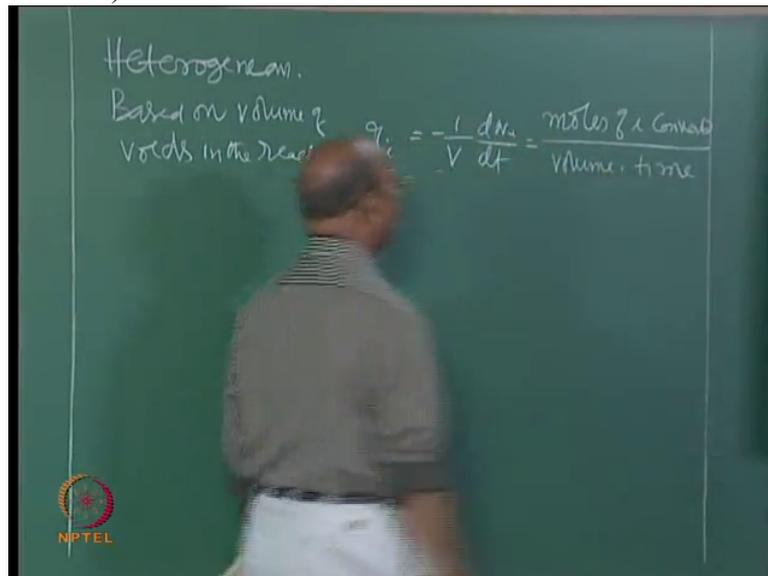
right? This can be of course, meter cubed per second you know, generally meter cubed per second.

I think in chemical engineering literature you get these values, those units in various forms. Right? If you take some of the books, deliberately they will give also feet cubed, Ok, there will be more feet cubed and all that, because I think this is required for us. You cannot say S I, I do not understand anything other than S I units. You should be able to convert one from the other.

Ok, otherwise consistently use only one system so that you will get the volume also in that particular system. If you are using everything in F P S system, finally the volume should be in terms of feet cubed, Ok so like that.

So this is the one, and you see here, we are now basing on voids in the reactor and that much you should know. We have the packed bed and you pack all the catalyst particles for example, in between the particles you have some voids and inside the particle also you have some voids, we are not talking about that. We are talking about only voids. Ok tell me, for packed bed, how much is the voidage?

(Professor – student conversation starts)

Student: Point 3 to point 4

(Refer Slide Time: 16:09)

Professor: Point 4, yeah. Any other guess? I am not saying it is right or wrong. It can be wrong also.
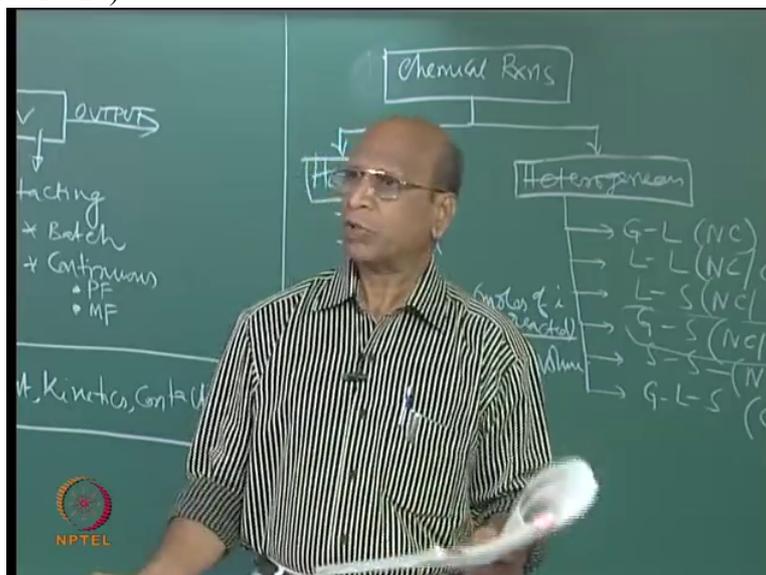
Student: External voidage

Professor: External?

Student: External voidage

Professor: External voidage

(Refer Slide Time: 16:24)

is what I am asking, yeah.

Student: Point 5

Professor: Point 5.

Student: Raschig rings

Professor: No, you do not answer. Because I think we simply say point 3, point 4; that is strictly valid for what?

Student: Raschig rings

Professor: Raschig ring means you know K K will use A K 47.

Student: (laugh)

Professor: Yeah. Right for Raschig rings it is point 4? What is this, I say? Two courses, B. Tech and M. Tech. I am talking about them, P h D scholars (laugh). I do not know you are a P h D scholar or M Tech? P h D, yeah, you see. So your Raschig rings are always having only point 4. Point 4 for what? This is what I say.

(Professor – student conversation ends)

Still we have L K G knowledge only. We do not have more than that. Our brain is not expanding. Yeah, tell me. You are just keeping quiet. Janhavi? Point 4 he said, for what? Point 3 5 to point 4, which packing?
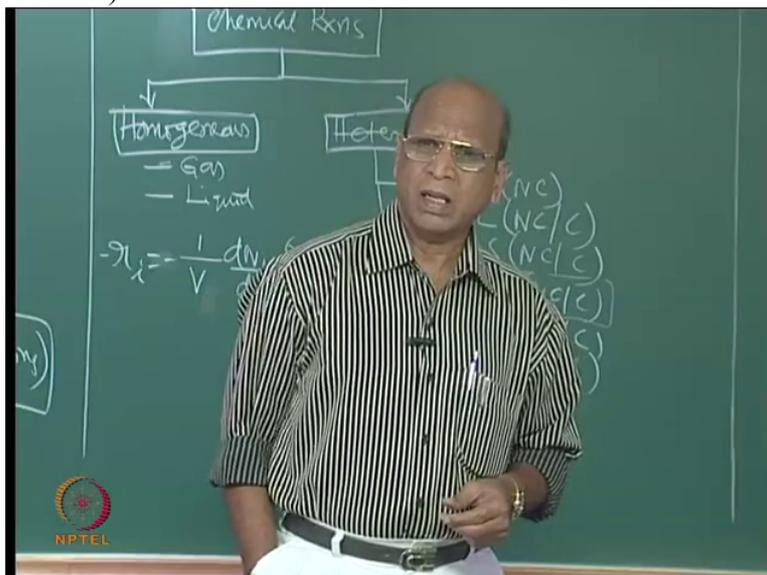
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And he said Raschig rings I said no. You can guess. There are many packings, no? Yeah, Sushmita? No idea? What is that?

(Professor – student conversation starts)

Student: Hexagonal packing

Professor: What is that packing, hexagonal,

(Refer Slide Time: 17:51)

HKP? Hexagonal packing, Oh my God, drop dead! No one will make hexagonal packing (laugh). How can you make hexagonal packing so easily?

Student: Regular and irregular packing

Professor: Yes?

Student: Regular and irregular packing.

Professor: Very nice answer. What is irregular, what is regular?

Student: (laugh)

Professor: Tell me.

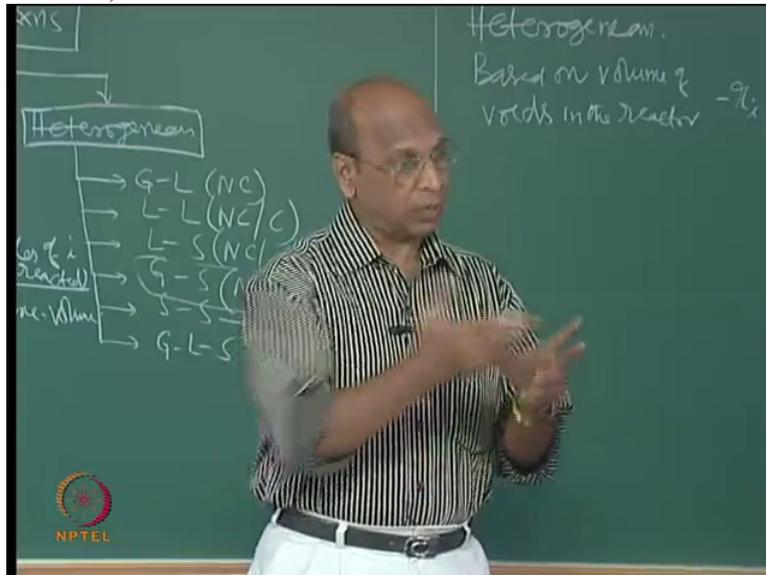Student: Regular means if

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0:18:12.4 is according to, like in which you want. Irregular means you just...

Professor: Dump; that is called random packing

Student: Random packing

Professor: Ok, yeah it is not. Because in regular and

(Refer Slide Time: 18:21)

irregular packings, Ok, there are thousands of variations. But this point 3 to point 4 will only come for one glass beads, Ok. Glass beads can be spherical, cylindrical, they can be Raschig rings, you know types, you know with hole, many things can happen. Gas beads are

Student:

Professor: Strictly for spherical particles. Please remember when you say point 3, point 4, Ok, strictly for

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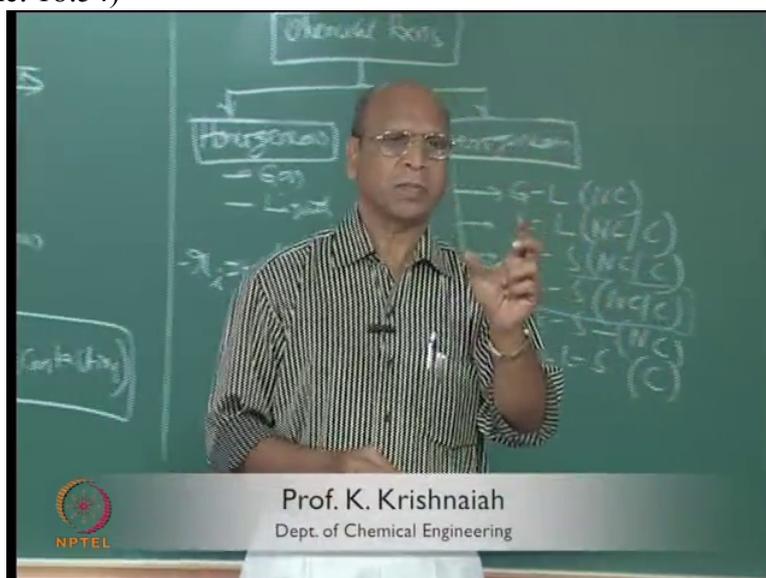
spherical packings.

(Professor – student conversation ends)

And as he said, I think you know, Raschig rings, Raschig rings will have how much? Any other, any other value? Point 6.Ok. Yeah Bell's 0:19:07.3 is, also around point 6. Ok so that is why you know, we have various packings, but except spherical packings, all other things will have higher voidage. Ok, good.

Yeah that is the based you know, this equation is based on. This is voids, right? Ok so then next one is, yeah so we can also based on volume of, volume of catalyst particles. So again this is, of course I can put here, dash, double-dash, i, yeah equal to moles, same thing, i converted or volume of solids per time, yeah so based on, based on weight of the particles.

Again I can write here, 0:20:43.2 Ok. Moles of i converted, then yeah weight of catalyst, cat we will write per time, good? Yeah.

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Another one can be, based on external surface, surface of particles. This is again minus 4...moles of i converted per surface area per time, yeah.
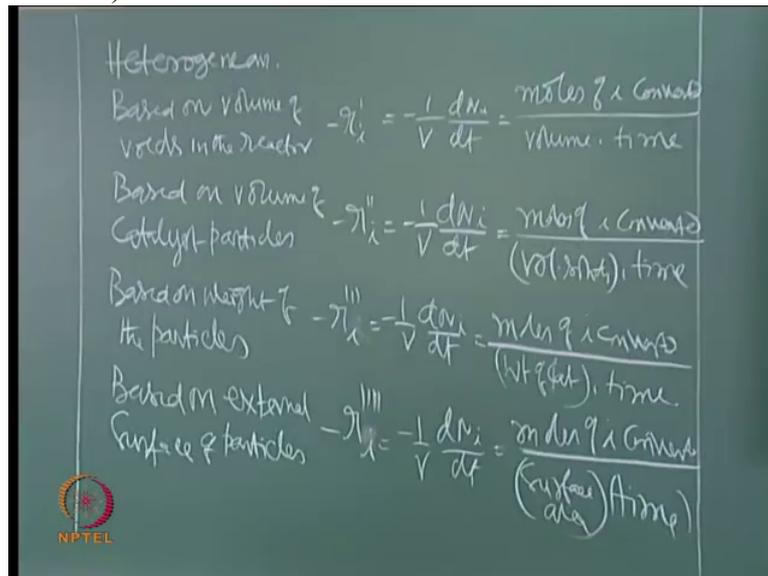
You are able to read?

The first one is always moles i converted per surface area, yeah, of what? Which particle, I have only particle, catalyst that is why I said you know, heterogeneous gas-liquid, gas-solid system, Ok, yeah so you have only, that is solid particles, yeah we will have definitely all these doubts because you have to specifically mention on which you are going to write the rate of reaction. This is very important.

Please do not take it away very simple definition and all that. No. Because finally what you get is only this one in the reactor, in the reactor design expression when you are calculating, like volume of reactor you calculate, right. So if you base it on volume of reactor, then you will get volume of reactor. If you get weight, you will get weight. If you get volume of solids, you will get volume of solids. Yeah, you were asking something?

(Professor – student conversation starts)

Student: 0:23:04.6

Professor: Oh, yeah, yeah, you are right, thank you. Yeah, you are right. Based on weight of the particle, very easy for me to write w and this is wrong, yes, thank you. Yes?

Student: Solid particles or catalyst particles?

Professor: Catalyst particles, yeah, Ok and all solids are catalysts inside the reactor, Ok.

(Professor – student conversation ends)

So when you are talking about packed bed where I have gas-solid catalytic reaction, we have taken only one example gas-solid catalytic reaction, right like for example ammonia conversion or sulphur dioxide to sulphur trioxide with using vanadium pentoxide, so many definitions are existing only for that. Still this is not the end. You can, if you are crazy, you can also base it on voids of the, voids inside the solids. It is not inside the bed. Inside the solids only I told you, sorry inside the bed only I told you that we have around point 4, point, point 4 for spherical particles, Ok, and you know point 6 if you have Raschig rings, and by the way, catalyst particles also are made in the form of Raschig rings.
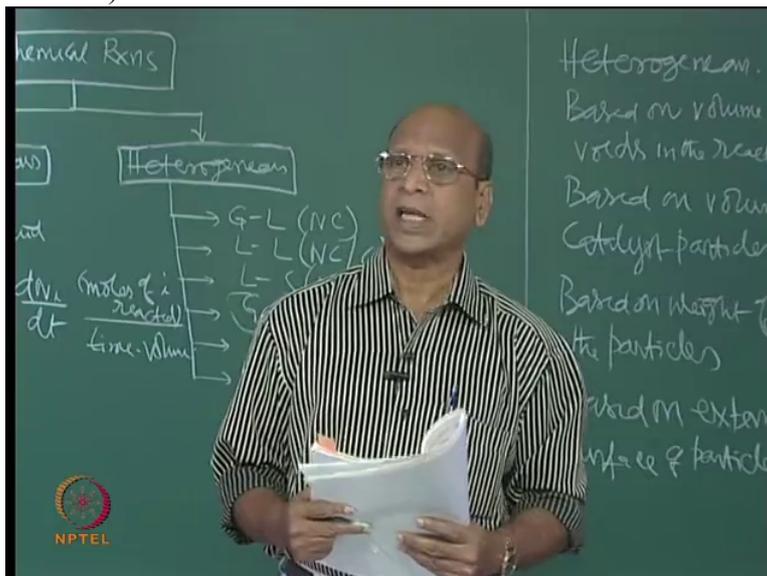
How does the Raschig ring looks like? Never seen. What is your name? I have forgotten. Just? Pooja, yeah. Pooja you have never seen Raschig ring?

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How many people not seen Raschig ring,
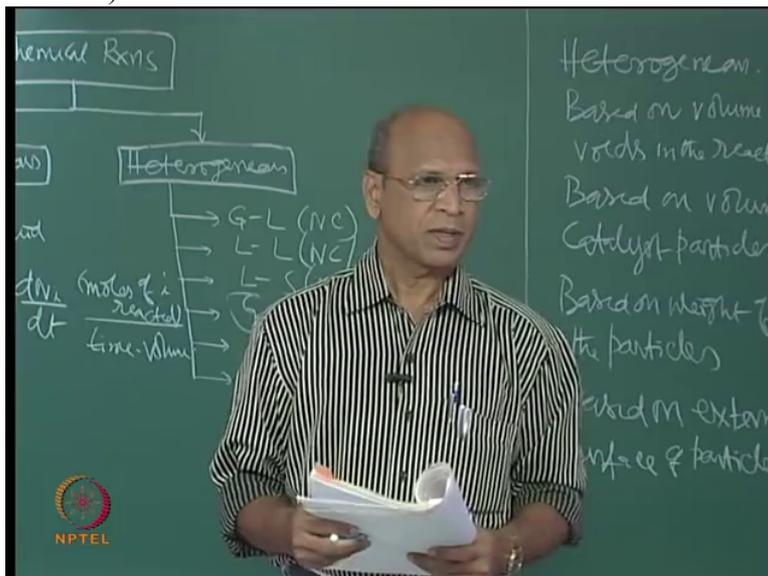
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frankly? Otherwise I will ask you to come and draw here.

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How the Raschig ring will look like. You have also not seen? My God!

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Ok can you tell them how, Abdul what is the Raschig ring? You also not seen?
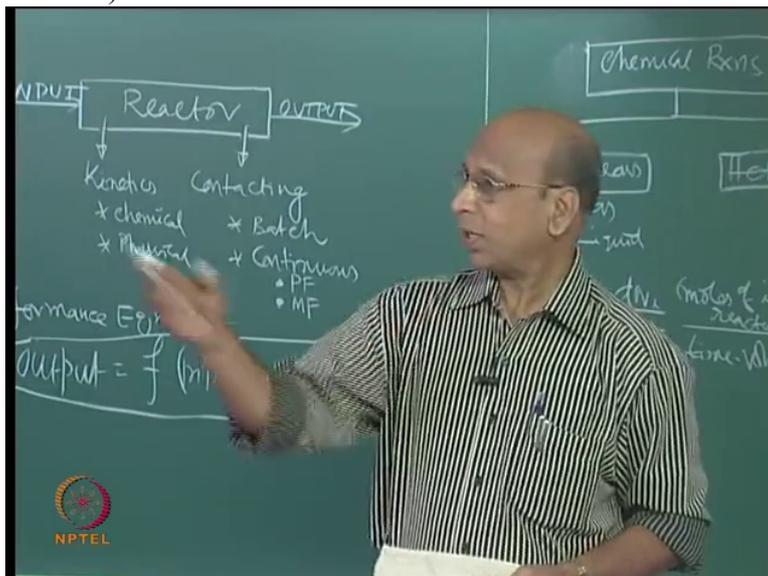
Ah...

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AC Tech how I say, they have lots of, they always have Raschig rings only 0:24:59.0. Ok
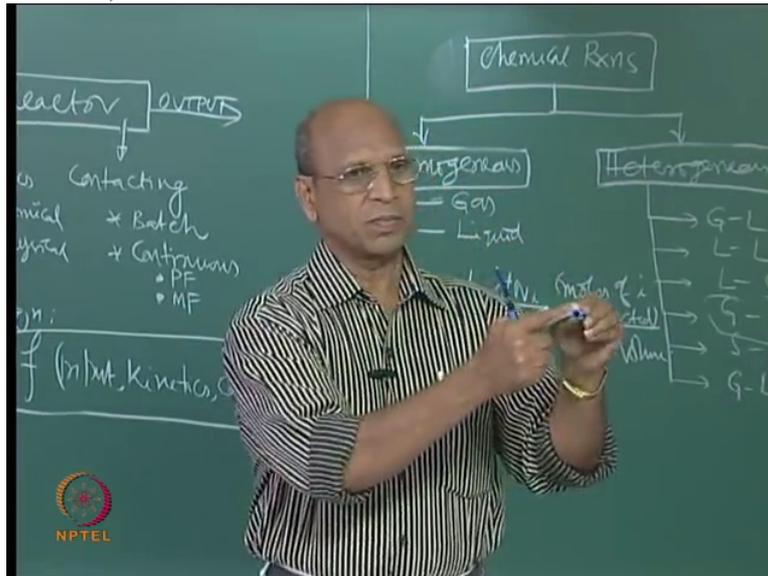
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Ranganathan, I am not asking if you have seen or not. In AC Tech, Raschig rings are not there.0:25:10.1 are more difficult to make. Raschig rings are very easy to make, Ok. Raschig ring is just a cylinder with a hole, Ok like you know, pen yeah.

This one, you just cut here. Take

(Refer Slide Time: 25:26)

this portion. That is Raschig ring. This is the simplest one because you are trying to utilize, if it is only cylinder, this is closed no; right so then area available for reaction is yeah, only the external surface. But now you put a cut here, cut here all over, if it is hollow, thickness may be 0:25:45.4, it should withstand the weight and all that then internal surface also is available for reaction.

So because internal volume also is available that is why it goes to 60 percent, point 6 is the voidage. And some people also use straight, like this exactly, this is the

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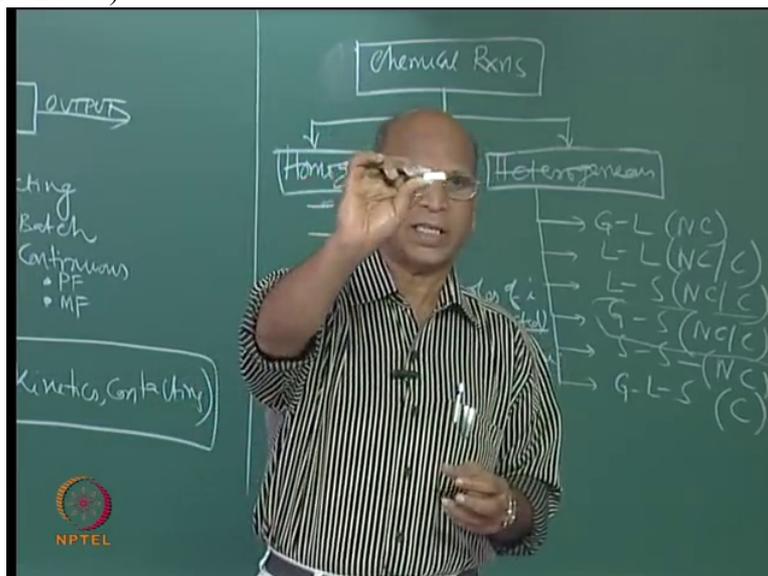
catalyst. It is a cylinder but there is no hole, Ok. Cylinders are very easy to manufacture in the industry for, as catalysts. Spherical particles are very difficult to manufacture on that scale, yeah.

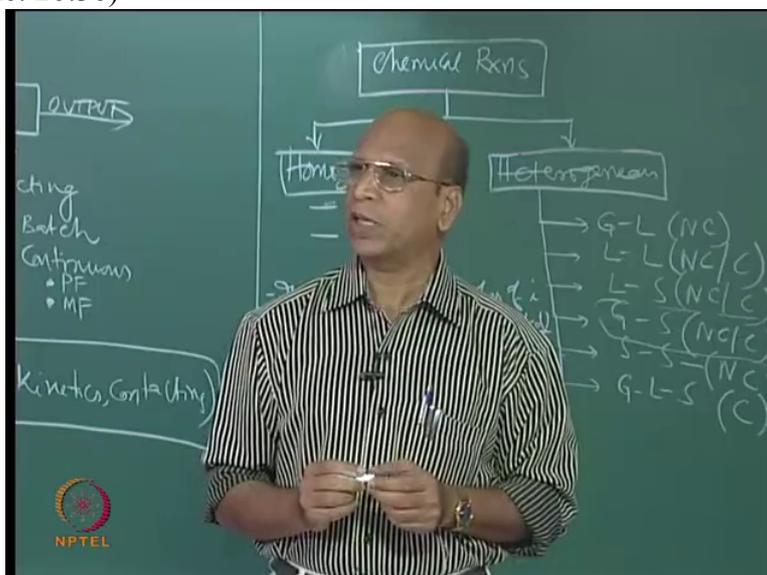(Professor – student conversation starts)

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Student: Other particles like your 0:26:27.5 and you are making powder

Professor: Very fine powder, no?

Student: Yes Sir

Professor: Are you M S scholar, P h D scholar, P h D...Why do not you do

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that experiment in your lab? Which lab you are in?

Student: Tanmay Basak Sir

Professor: Tanmay Basak Sir, Oh yeah, in I think in that Transfer Operations Lab, you take a cylinder and then you try to pour that powder and try to find out, what is the voidage?

Student: What I can do is I can place this support, you know ceramic…

Professor: You do whatever you want, but tell me what is the voidage.

(Professor – student conversation ends)

No it is good. That is why many people think that people who are working, who are doing the experimental work, the theoreticians feel, the people who are doing experimental works are like laborers, Ok. But I think laborers definitely should have much more brain than the theoretical people because theoretical, nowadays that theory, you are not proposing E equal to m c square, Ok. You are only trying to solve some mathematical equations.

But experiment when you try to do, how many things you have to imagine in your brain before you start the experiment. Even nut and bolt you have to choose, Ok, literally you have to choose in our department because we do not have nuts and bolts now in the department. Ok we do not want to have any nuts, Ok (laugh). Yeah so I think it is very, it is not that easy.

Everything you have to imagine how do you do this experiment, for the experiment to be done? That is why many people take the easiest route, go to computer, take one differential equation, solve, change boundary conditions, submit. The real engineering thing will come only when are able to verify whatever theory you have done, you know in your thesis with an experiment. So that is why most of the engineering P h Ds are, M S you know, research problems must be having both the components, theory and experiment. Otherwise you are not an engineer.

In fact it happened. When they go for interviews here, you know, what is that, placement, people asked have you seen, you know, what is a rotameter. They said no, we have never seen the rotameter. They were very angry, the people who are working theoretically. Ok. They are very angry and they wrote this big letter to director at that time. It was I think 15 years back, Ok. What is this? What kind of training you are giving in the chemical engineering department? They have got M Techs and P h Ds but they never seen a rotameter, Ok.

You may ask, so what? If I have not seen rotameter what will happen to this world? Nothing will happen to this world but only thing is that you will not get the job. Correct, no? They definitely want some information about rotameter, I think some flow meters, Ok. So that is why I think that is a good question.

I think I also told you, when you put very, very fine powder, what should be the voidage? It is nice, spherical particles you will get that. But if you have powder, that too irregular powder you may not have each and everything as perfect sphere, then definitely it will be point 2, point 1, much less. But it will be challenging for you to determine exactly what it is.

Ok because you are using very, very fine powder, for example talcum powder, you pack it and then or when talcum powder is put in that container where you use it with holes, perforations you know, you spray there and all that, yeah so then what should be the voidage there? That depends on again pressure, how much pressure you are applying when you are packing that. So that is not that easy to determine.

That is why powders we never use in packed beds, right? We use only minimum 3 m m particles, 5 m m particles, of course in industry as I told you the catalyst, if they are using spherical, even then it will be half an inch particles, 10 m m, 8 m m, 6 m m like that. Maximum I told you 18 m m. 1 inch, 2 inch no one will. Because simply we are losing surface area.

But if you are going to lower and lower, 1 m m, point 5 m m, 2 m m, the pressure drop is increasing, because you know normally, theoretically there should be no change in voidage if you have perfect spheres. But who can make a perfect sphere? Even God cannot make perfect spheres, really. That is why he made all the planets and most of the planets you see, they are bulging in the middle like all of us.

(Professor – student conversation starts)
Student: (laugh)
Professor: Yeah, really, because they also rotate you know.
(Professor – student conversation ends)

Because always the first indication of prosperity is this, Ok. So people look. That is why I used to analyze people in terms of straight lines, I told you already? No. Always see the people as straight lines or cylinders or spheres, Ok.

Straight line will be something like this.
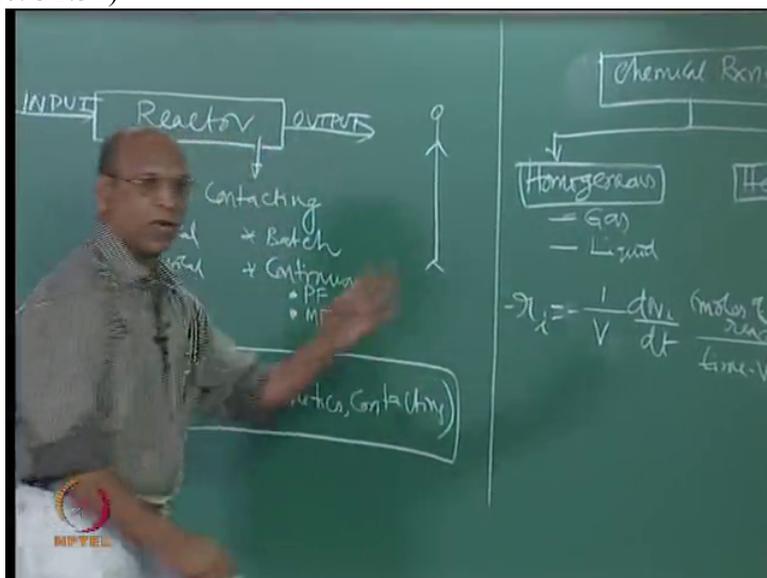
Somewhere you have legs, somewhere you have hands but most of the time you see a single line. We can see some of the people, when they are walking, Ok, all this, you know. Long time back in Telugu, I do not know when some of the people may be knowing, Telugu people, there used to be a comedian called Ramana Reddy, Ok, yeah. He was a straight line.

Because he does not have any other organ, except you know, one-dimensional. You cannot put any other organ there, no. Ok, yeah.
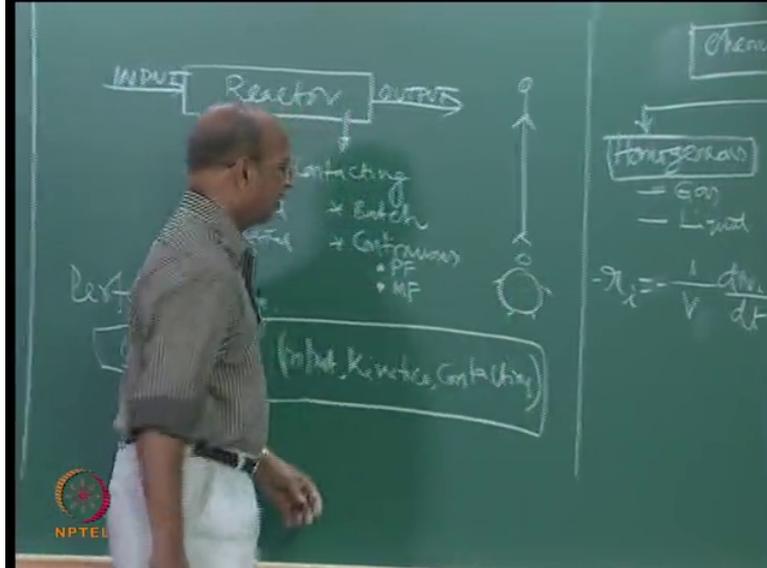
The other person what I have seen, the other extremes, yes, was one of these singers where

(Professor – student conversation starts)

Student: (laugh)
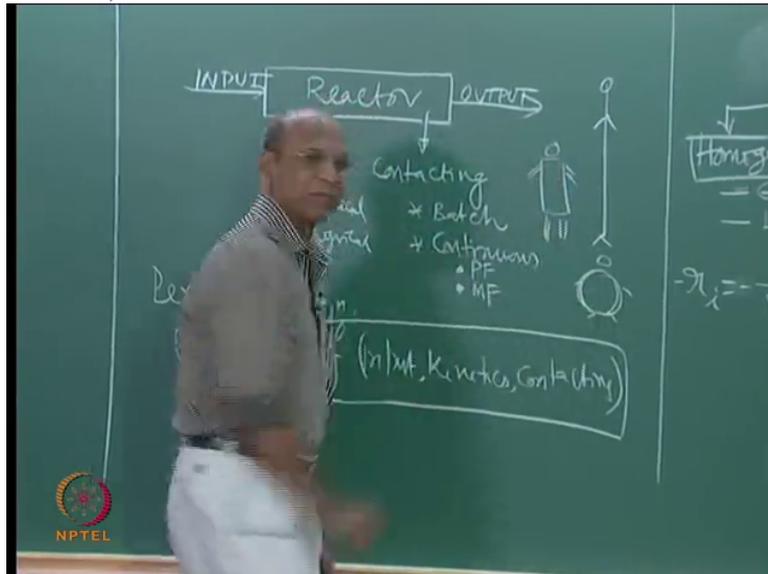
Professor: This is not sphere? You cannot see, head only small, legs and all that hidden somewhere, (laugh) so this is the one. So as engineering I am approximating that one as spheres. You can see that, Ok. And most of us are looking like this. Yeah. Ok, cylinders.

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That is how, I think you know we can see, we can look at the people and then think that, Ok my God, straight lines, spherical particles, and cylinders.

(Professor – student conversation ends)

You can also divide them and use them as catalyst if you require. But this is very bad catalyst. Because packing is not possible so easily. Even this also is irregular but that is what people use mainly in industry most of the time because you know extrusion....

How do you make catalyst? They will identify what is the material and they will make as the paste and they will extrude through the extruder like noodles they make no, noodles also extrusion only but they cut. Normally l by d equal to 1. Normally. It can be even 1 point 5 but most of the time, l by d that means if diameter is 1 centimeter, length also is 1 centimeter. That is the kind of cylinders. Those cylinders they pack.

And as Janhavi was telling, you know, irregular, random packing when they do, you will not get uniform porosity or uniform voidage across any cross-section. That means when I take packed bed and cut at one point, I look there, so the voidage may not be uniform as compared to another cut just above.

That is why we take what is called superficial velocity. You know why do we use superficial velocity? By the way what is superficial velocity? I am talking as if all of you know what is superficial velocity. Yeah what is superficial velocity?
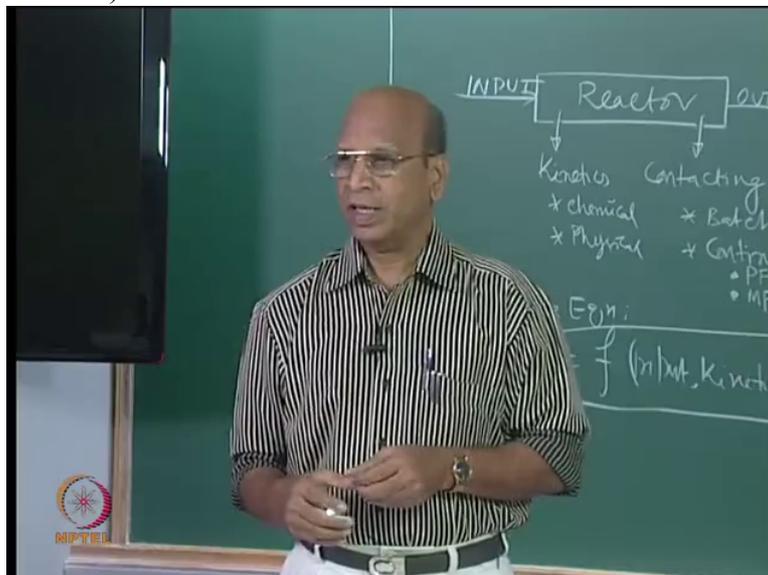
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(Professor – student conversation starts)

Student: Velocity in a

Professor: What is your name? I want to remember names.

Student: Abhijit

(Refer Slide Time: 34:19)

Professor: Abhijit, yeah. Abhijit no? Ok. I will equate with our Abhijit.

(Refer Slide Time: 34:26)

Student: And 0:34:27.8 divided by that area.

Professor: Which area?

Student: Velocity divided by

Professor: Velocity? Velocity you cannot divide anything. You have to take only volumetric flow, which area you are talking?

Student: You take void area, when no catalyst is there, nothing is there.

Professor: Yea, yeah, superficial velocity, correct, superficial velocity is based on only empty cross-section,
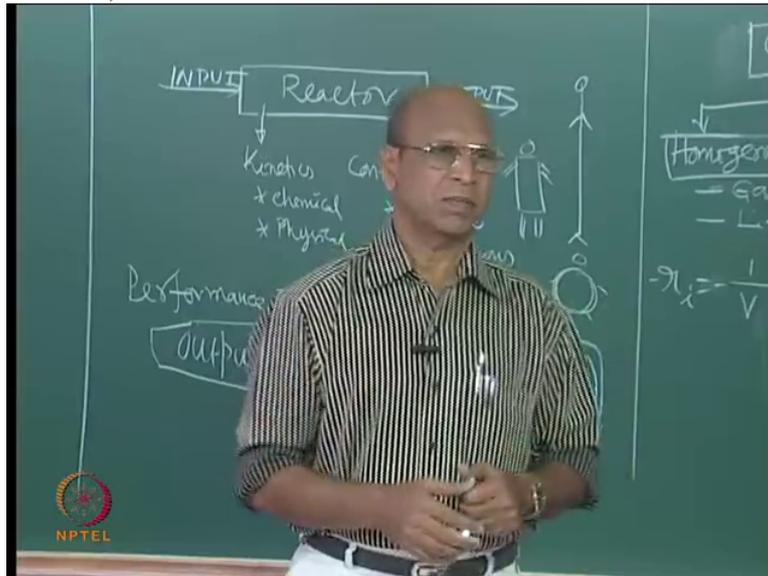
(Professor – student conversation ends)

But in most of the packed beds, you need packing definitely for the catalytic reaction to take place but in spite of that we always refer to superficial velocity. You know the reason why? The reason is exactly I know what is superficial velocity, Ok. Because it is empty cross-section divided by, yeah volumetric flow divided by empty cross-sectional area, Ok.

On the other hand, if I put packing, if it is not uniform voidage, at every point velocity is changing. So I do not know how to correlate that. So that is why a very good known parameter I will take. I will express all my correlations in terms of only superficial velocity where we know the diameter of the column, we know the volumetric flow rate, so we get the superficial velocity.

If all the correlations are developed in that way, then it is easy for us to use them. Otherwise the voidage will change depending on the packing. The voidage will also change depending on you know, you have irregular packing or even cylinders also it is not uniform.

Only perfect spheres if you can pack them, that too maintaining l by d, this time not l by d, d by d p, diameter of the column divided by diameter of the vertical minimum 10 and above if you use, then only you will have the uniform voidage. Otherwise what will happen, near the walls you will have more voidage, at the center you will have less voidage.

But by increasing the diameter and putting only 100 particles only for example across, across one diameter 100 particles if you are able to put, most of the non, you know non-uniformities will disappear. That is why we say, assume, people who are using these theoretical equations, all assumptions first they do.

Assumption number 1, use, I mean assume spherical particle. You will never get spherical particle. Assume uniform voidage. You will never get it. Assume no Wall effects. Ok, that is Ok. You can get it, because depending on diameter of the particle and diameter of the tube, you may be very near to that assumption, right. So that is all that we do, good.

So what is that I was telling now? Yeah, out of all these,

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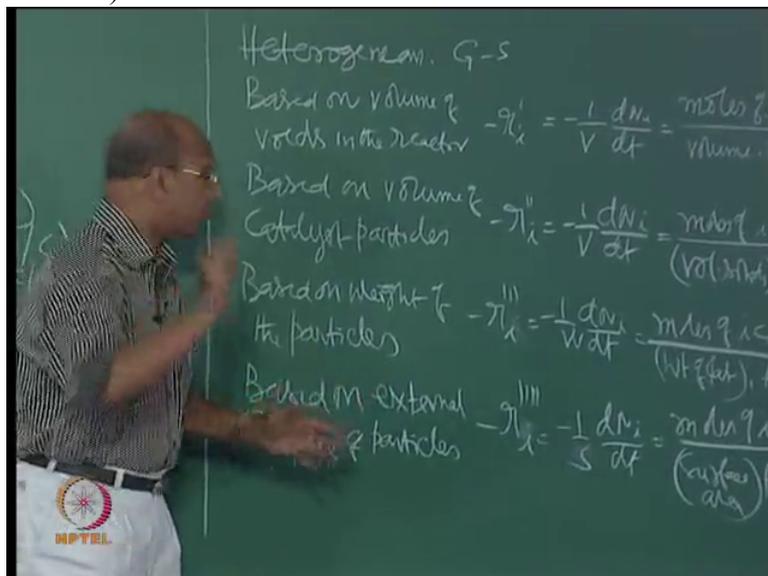
as engineer which one will you use, is only for just gas solid catalytic reactions, which is third one?

(Professor – student conversation starts)

Student: 0:37:17.7

Professor: Yeah why? Correct.

Student: Easy to measure.

Professor: Easiest to measure. Easiest to measure. What is difficult to measure out of all that?

Student: Surface area

Professor: Surface area, you will never get perfectly all the surface area that is available for the reaction.

Because even when you are using different techniques, right, B E T may give you some good information but mercury porosimeter this that will not give, will not cover the entire range of pores. Ok, so that is why, like this you have to write all possible things and then choose one of the easiest rate. Like for example if I have liquid-liquid reaction which is the easiest way to express?

Student: 0:38:04.6

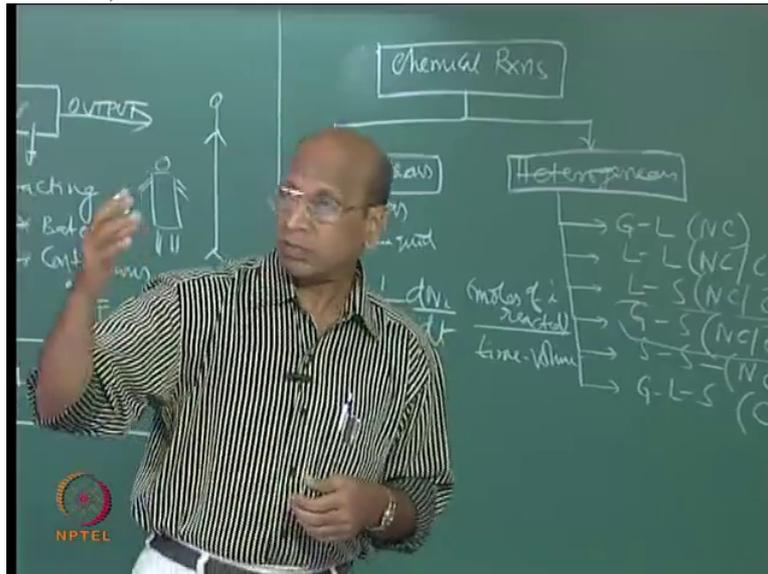Professor: But you have in the volume,

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both the things.

Student: Volume of the reactor

Professor: Yeah, very good, volume of the reactor you can express. What is the most difficult to get?

Student: Interfacial area.

Professor: In fact,

estimation of interfacial areas are very, very difficult. Same thing even with gas-liquid system where you have bubbles. Gas and the liquid as bubbles. So then again you will have same problem. So that is why you have to now understand that the first problem with heterogeneous system that comes is definition of rate itself.

(Professor – student conversation ends)

And one example I can give here itself G-L-S. When you have three, three
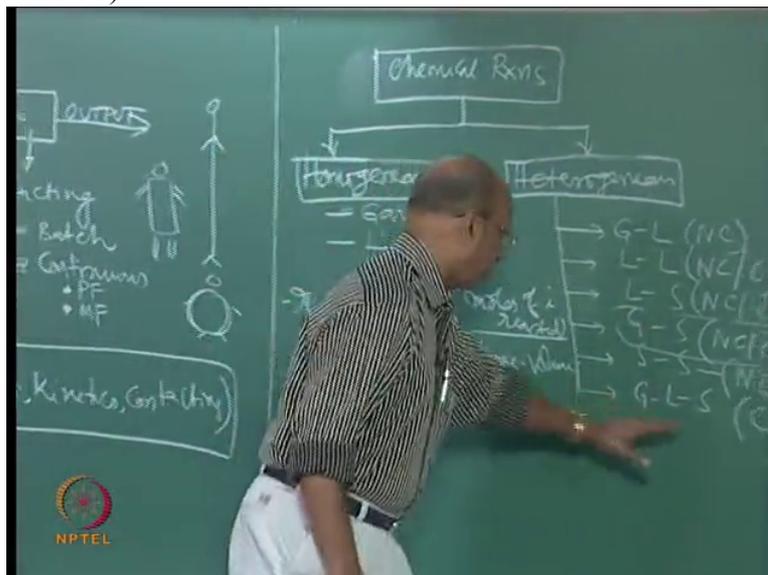
phases most of the time people express as bubble-free slurry volume, moles converted per unit time per unit bubble-free slurry volume. That means again bubbles; they may be of different sizes, different you know shapes.

You will not have again spherical bubbles; spherical bubbles all the time, right and also you will not have uniform bubbles all the time. So that is why they simply eliminate saying that Ok, let me express the rate for this as moles converted per unit volume of bubble-free, yeah bubble-free slurry that means solid volume plus liquid volume you take.

But that is not the only unique way. Some people may say that only bubbles, Ok. I think when you take, this time also we will tell, in the next semester we will actually derive an equation for the rates for, you know slurry bubble columns, slurry bubble columns also sometimes called slurry columns or slurry bubble columns.

So there you will know it is
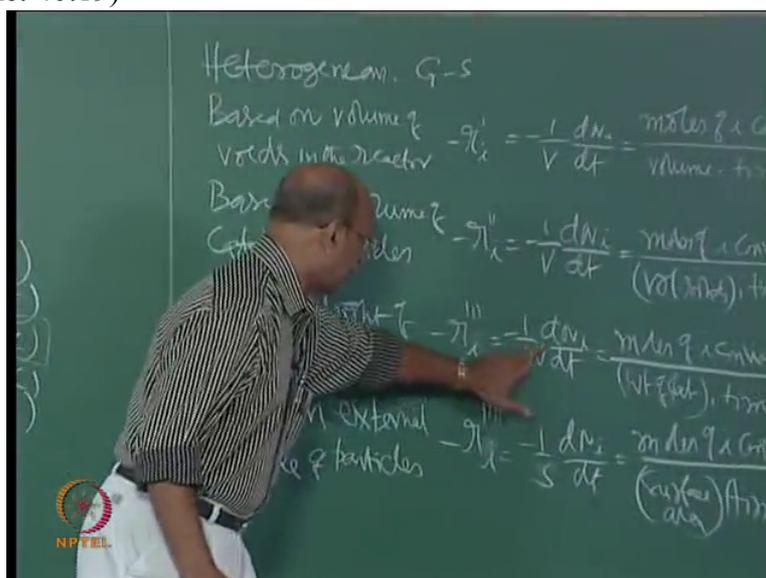
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most important thing is bubbles there first, a mechanism you will just look into. Ok. So that is what is happening, now with all these rates you have to

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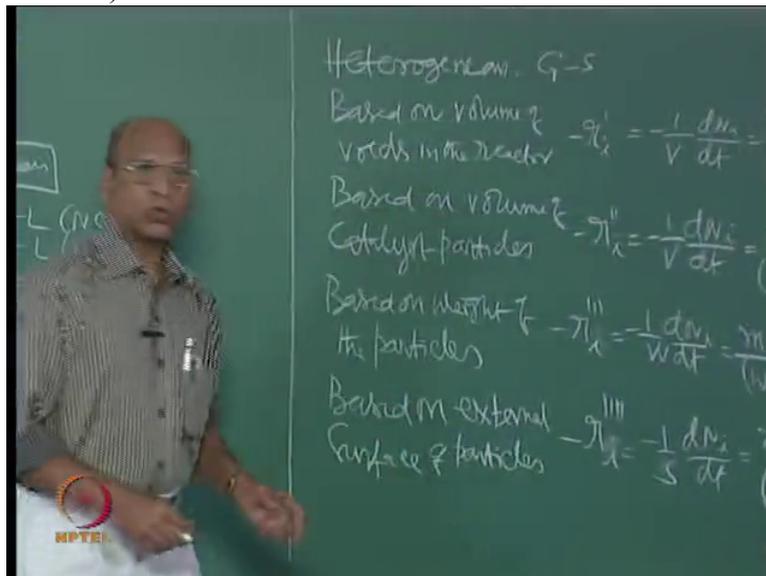
choose one of the easiest one which you can measure and industry can use that very easily. So as I told you again I am repeating, when you use this equation,
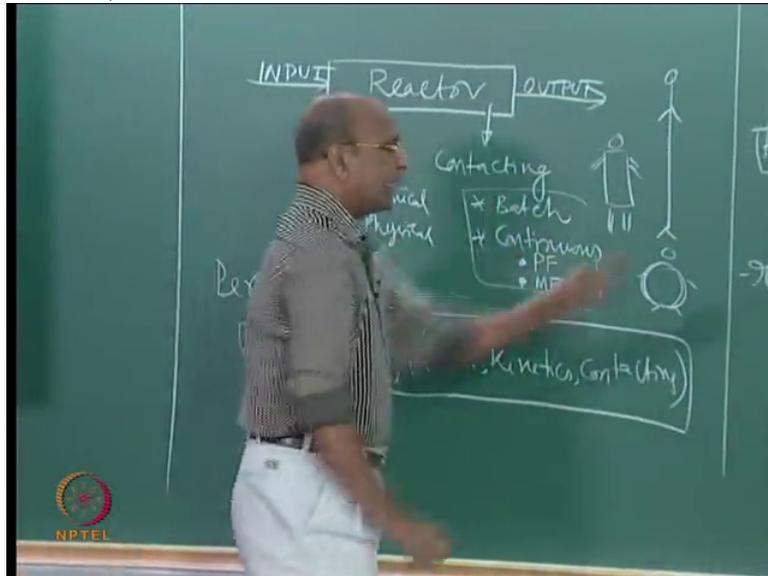
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then you will get directly weight of the catalyst, Ok. Or when you are using surface area, directly you will get surface area of the catalyst. Then you can convert.

Finally you should have only volume; converted into some diameter and some height. That is what is ultimate no, shape of the reactor, Ok. Spherical reactors many people won't use; very difficult to make again, spherical reactors. Most of the time either tanks only right, cylindrical. Most of the time it is only cylindrical. So that is why you have to choose a diameter, you have to choose a height. Good? Yeah.
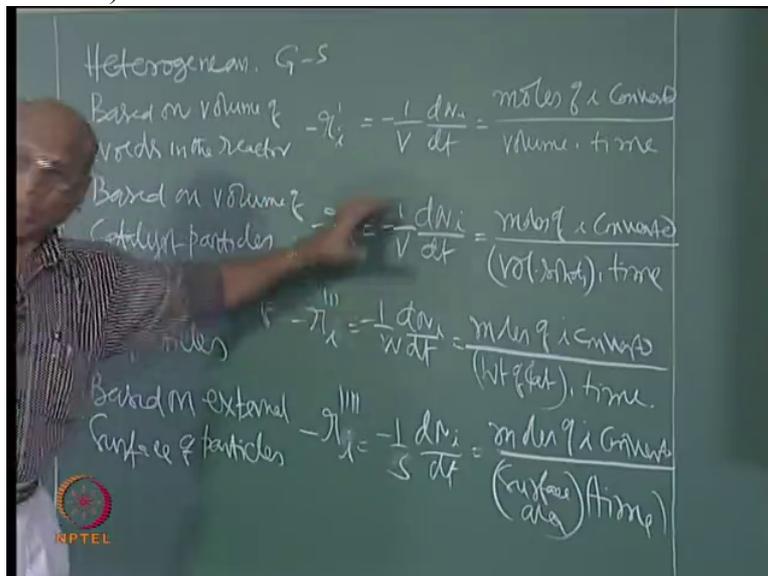
So I think I have covered, wanted to cover many but this time I think yeah, I thought of doing even batch reactor so next, tomorrow class we will concentrate on contacting.

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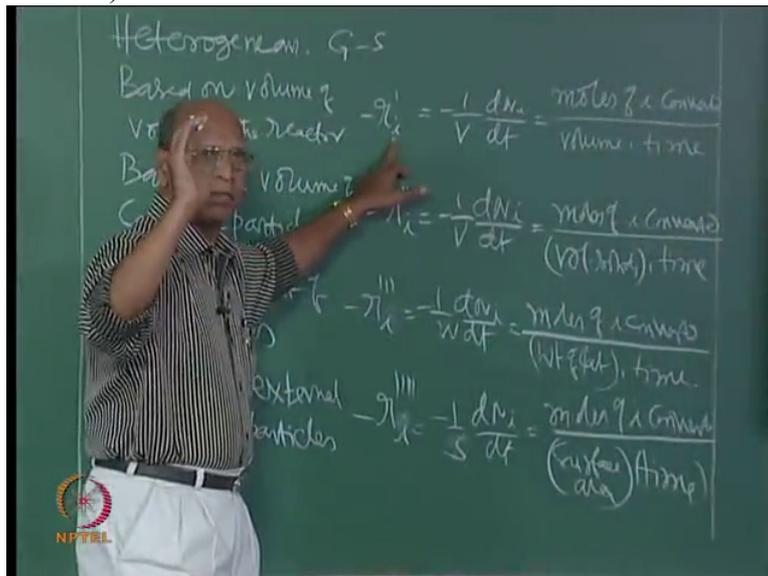So this is the information what we have now. In fact this is what

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we have to write also in the design expression when we are writing the balance.
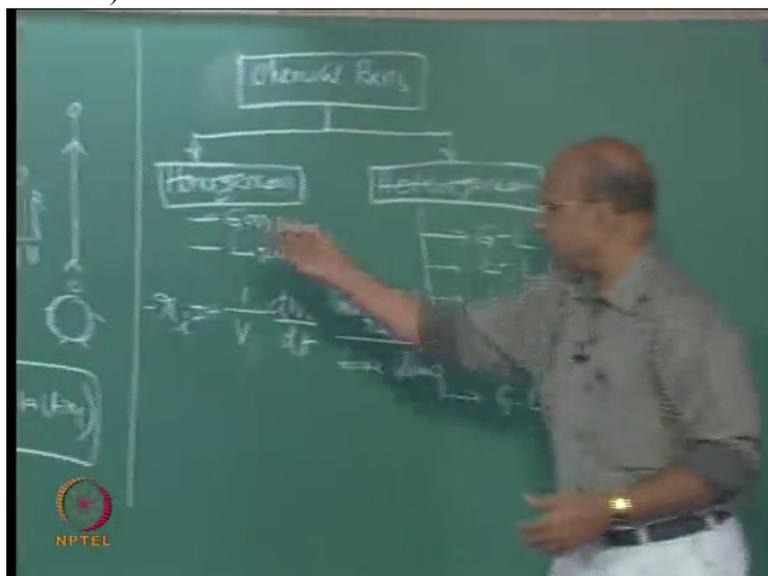
That is why I thought I will just say the definition of the rates and all that, our key reactant always is A.

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That is why you call you know minus r A, right. So we will use that information to now write design expressions for batch

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and then continuous, and I also discussed with you when do you choose continuous, when do you choose batch.