Chemical Reaction Engineering 1 (Homogeneous Reactors)

Professor R. Krishnaiah
Department of Chemical Engineering
Indian Institute of Technology Madras

Lecture No 19

Kinetics of Heterogeneous Reactions Part 1

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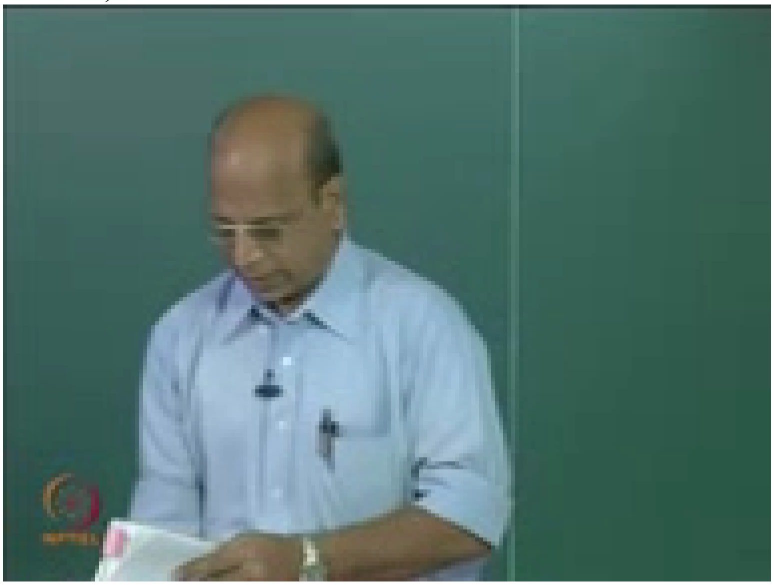

So yesterday we have been discussing, discussing about kinetics, right? Oh, not yesterday, day before yesterday, Ok. Ok. So we

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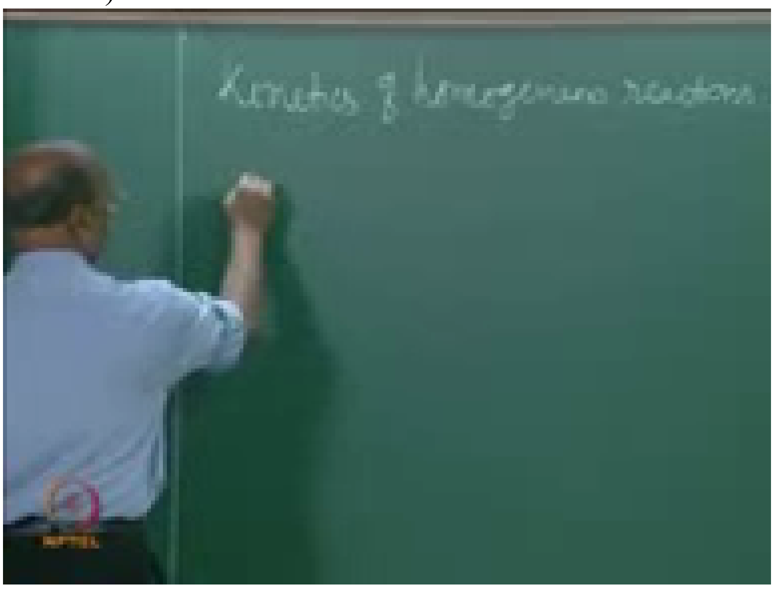

told that this will be f 1 in general, C A T… yeah, Ok?

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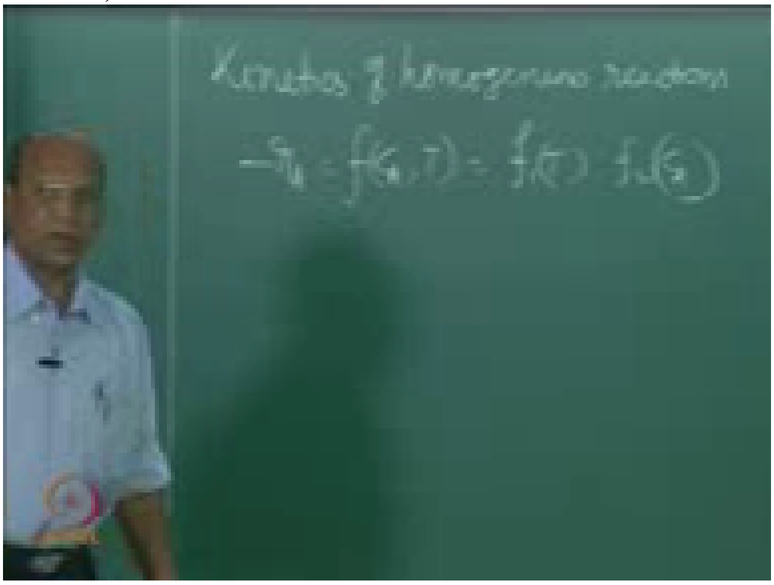

I think we have thoroughly understood what is this f 1 T because whatever format you use, somehow with simplifications and all that you will only end up with Arrhenius equation, Ok. So that is why that is fixed for us. Only Arrhenius equation is valid and I think no other time we will go beyond Arrhenius equation, right? For temperature how it affects K value, Arrhenius equation, right, good.

So now the second one I have written for, Ok, f 2 C A format will be, I have written 1 and C A and all that, Ok. 1 C A squared C A cube all that we have written and all that was only for A going to R, products, Ok, good. So that is one format for us. And then I think already, those things we have written already, right?

And also it need not be same simple C A squared or C A cubed or C A to the power n also we have written where n can also be an integer and we have also written Michelis-Menten type where C A by M plus C A. Or it can be C A by; need not be Michelis-Menten equation. You know at the end we can also have, this is C A squared by M plus C A.

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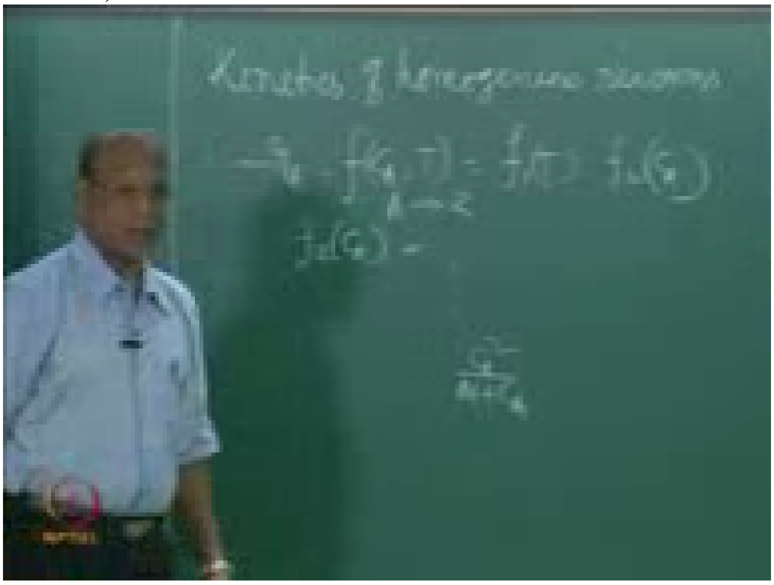

Or C A by M plus C A squared.

That means what I am trying to say is you cannot say that what form you will have unless you do the experiment, Ok. That is the message finally for you, good. So this is A plus B. Now I can have also various types of stoichiometric equations. It is not that always you have A going to R.

It can be A plus B going to R or it also

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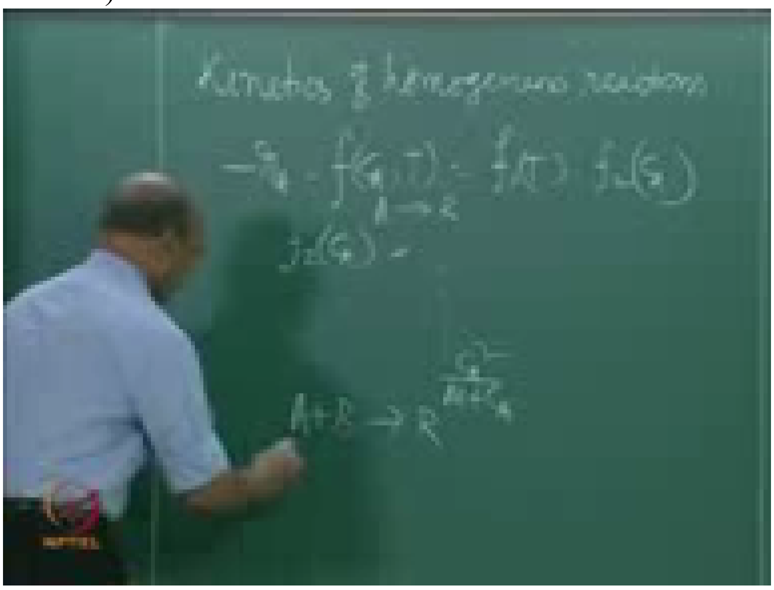

can be A plus B going to R plus S.

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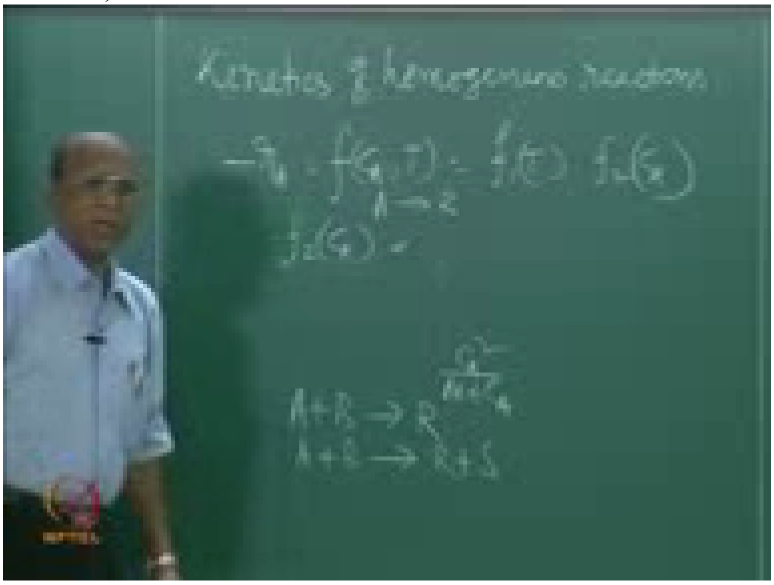

Now I say you can write anything I say because now it may be 2 A plus B going to 2 R plus S. Right. Even here, it may be 3 A plus 2 B going to 1 R, right? Like that any combination is possible. Not only this. Unfortunately we also have another category, this one R plus S. What is this?

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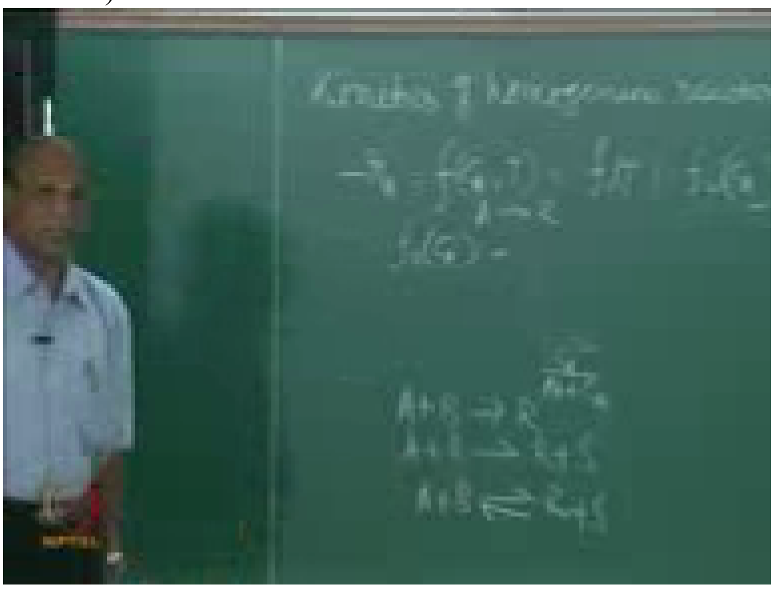

Reversible reaction.

Now again, any combination. This is 2 A, it may be B. It may be half R, it may be, you know another 2 or 3 S, right? I mean if I write for example, like this 2 A 3 B may be, Ok, this is again may be R and this may be 3 S. If I say that what is the order of your reaction, what is your answer? Sorry? 2 A plus 3 B

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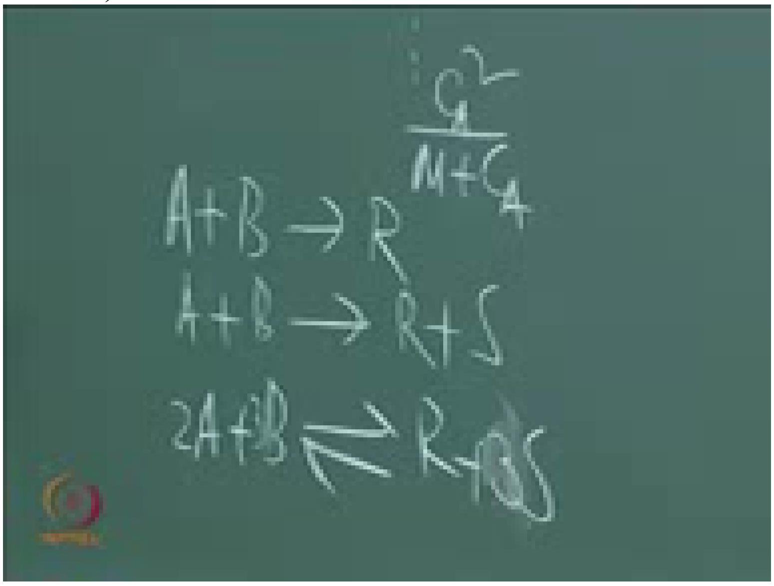

going to R plus 3 S in reversible direction.

(Professor – student conversation starts)

Student: You can say that it is non-elementary

Student: Non-elementary

Professor: What do you think?

Student: Non-elementary

Professor: Why? Because they are telling? Why is it non-elementary?

(Professor – student conversation ends)

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If it is elementary, what is the order?

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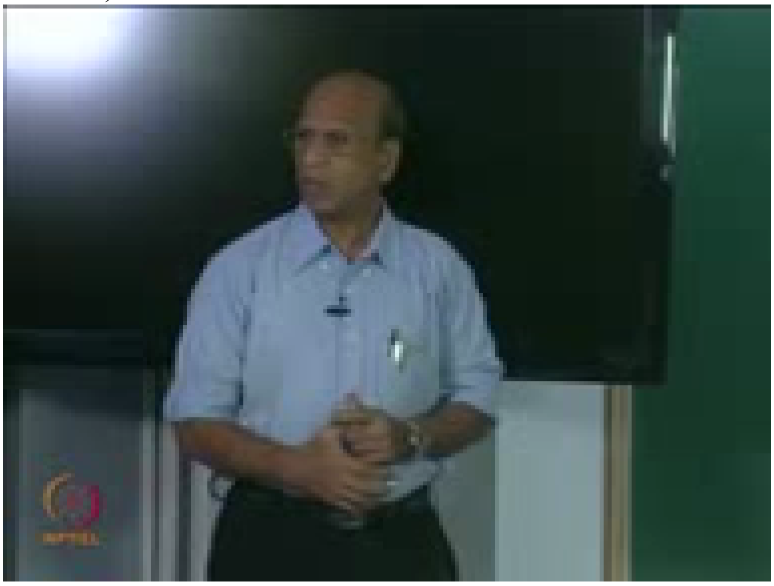

That is not possible you know, because Nature wise, 3 molecules coming together and then colliding itself, probability is very, very less. 4 coming almost zero, and 5 coming almost, almost zero. Ok, so that is why, you know that should be some kind of yeah, non-elementary type. May be you may end up with first order or second order, that is also we do not know.

With respect to this, it may be first order, with respect to this; also it may be

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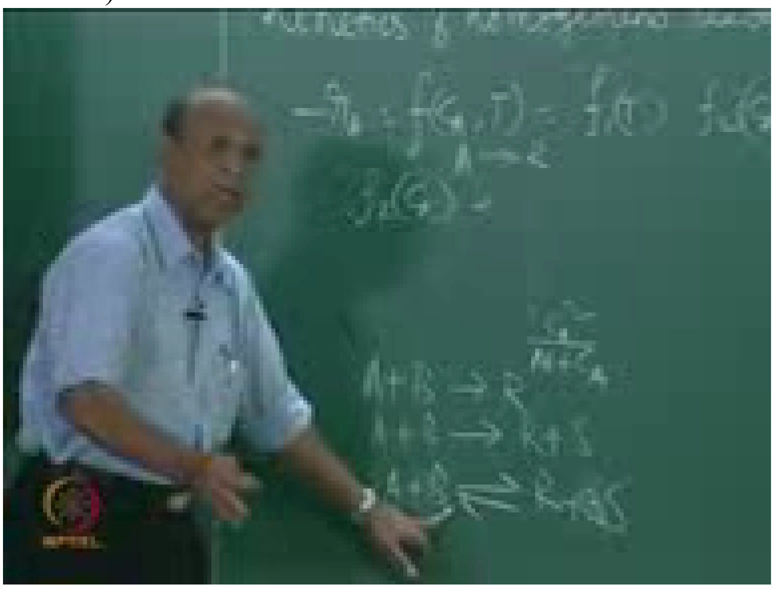

first order. But message is that all the time, unless you do the experiment, unless you solve the problem on your own, you cannot

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know what is the order. That is the message.

And unfortunately that is why you should appreciate me; you do not appreciate me anytime you know. So why I am telling you have to appreciate me is I told that kinetics is very difficult and contacting is very easy. Ok. How many reactors ideal things I can imagine in my mind? Only 3, that is all. You cannot add any more. Even if you add, it would be part of these 3 only, Ok.

But how many equations we can write? Another type I am going to write now. A going to R,

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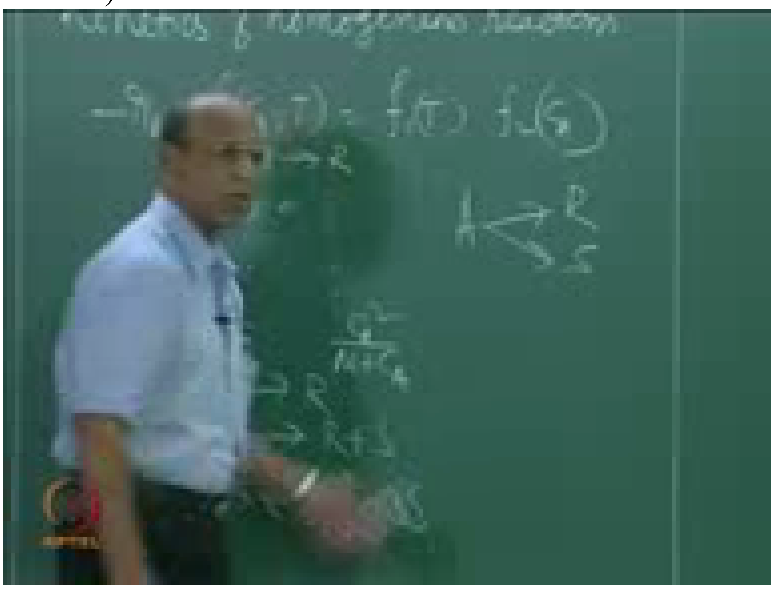

what is this reaction?

(Professor – student conversation starts)

Student: Parallel

Professor: Parallel. Now again you may have A going to R going to S going to T

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Student: Series

Professor: Series reaction. Now you can have another type, A plus B going to R and R plus B going to S?

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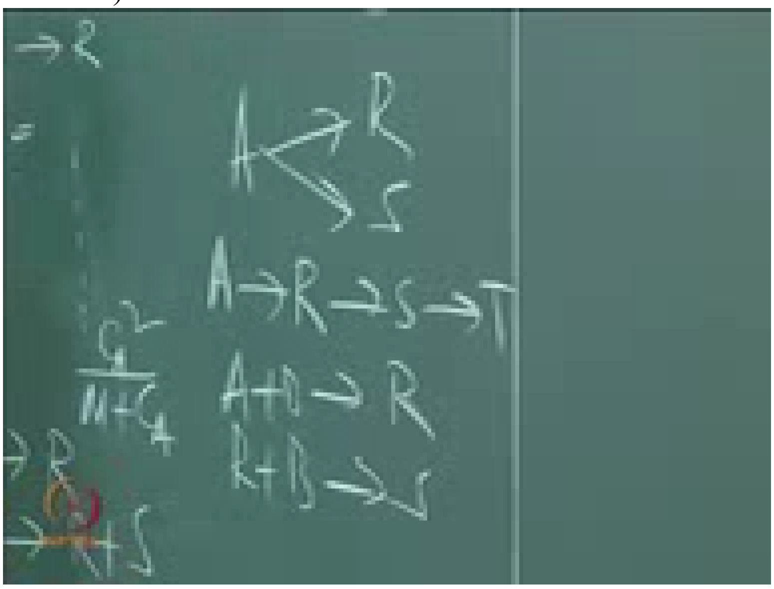

Student: Combination

Professor: Series parallel combination.

(Professor – student conversation ends)

So but unfortunately, Gopinath, I think for everything, every reaction like this, you have to find out kinetics. Kinetics means rate equation. What kind of rate equation you have? That is why I tell it is hell. Because I think kinetics gives you hell where as contacting gives you very simple information, only 3 and that too when we imagine ideal conditions, much more simpler equations, correct no, much more simpler equations, absolutely there is no problem in understanding contacting pattern.

And you do not have to understand anything in input. It is market survey. What do you understand? You go to market and then how many people have headache in the world, find out total number multiplied by, you know per tablet, you know we have to take 3 tablets a day, too much headache means

(Professor – student conversation starts)
Student: (laugh)
Professor: Yeah so may be how many grams normally it will have?
Student: M g, gram.
Professor: Yeah, all of us know,

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because everytime some. I think till now there is anyone who has not taken any headache tablet? You have not taken? You have also not taken. Why you have not taken?

Student: (laugh)

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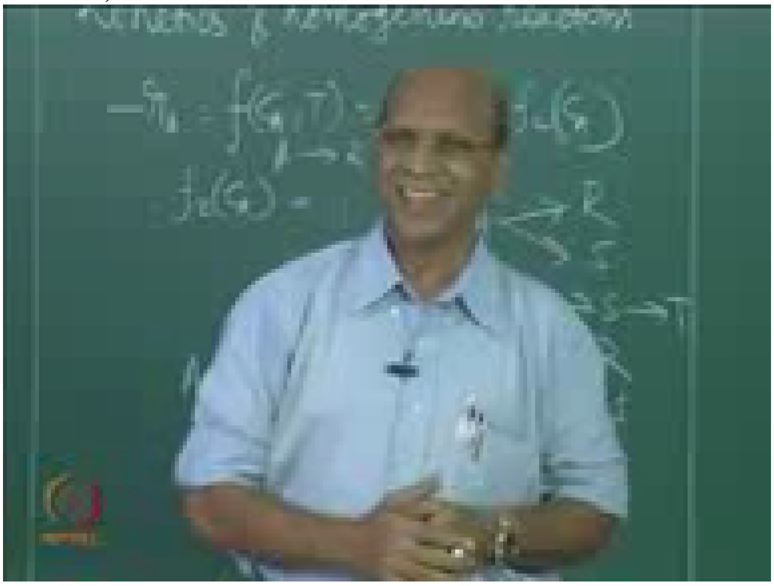

Professor: You do not get headache? But head is there or...

Student: (laugh)

Professor: (laugh). Head is there. I do not know, I think if you have headache, I think you should get. If you have head, yes Rahul, I think you should get headache, I say. I do not know. Without head I do not know. Yeah you also do not get. You are Abhijeet, no?

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Student: Soumen

Professor: What about you, your name?

Student: Rajendra. I do not get headache.

Professor: You do not get headache.

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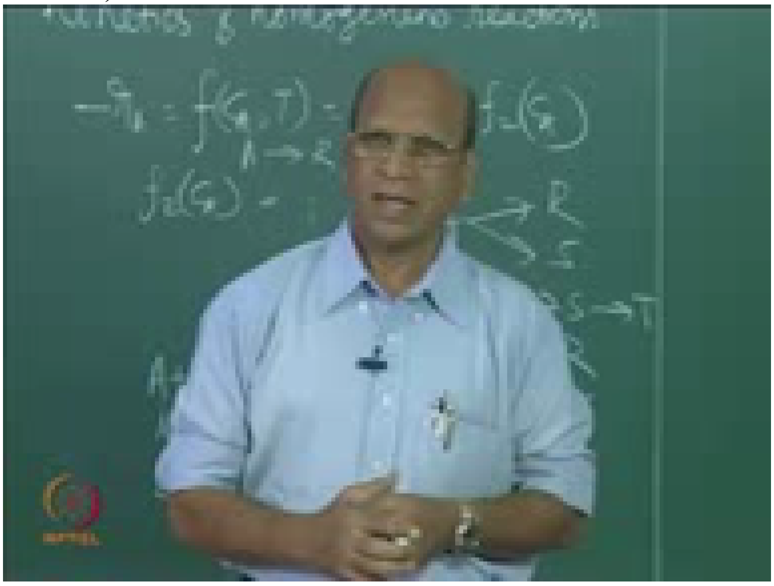

Student: Whenever I have some headache, I have 0:07:43.4

Professor: 0:07:44.7 I say

Student: (laugh)

Professor: Other alternative, why do not you tell us? What do you do then? Meditation?

Student: Not meditation. I watch movies on TV

Student: (laugh)

Professor: This is very good, I say. We get headache once we see TV only. (laugh). His headache will go if he sees the movie. So very good, nice.

(Professor – student conversation ends)

Ok, anyway, 500 m g, into 3, 1 point 5 grams,

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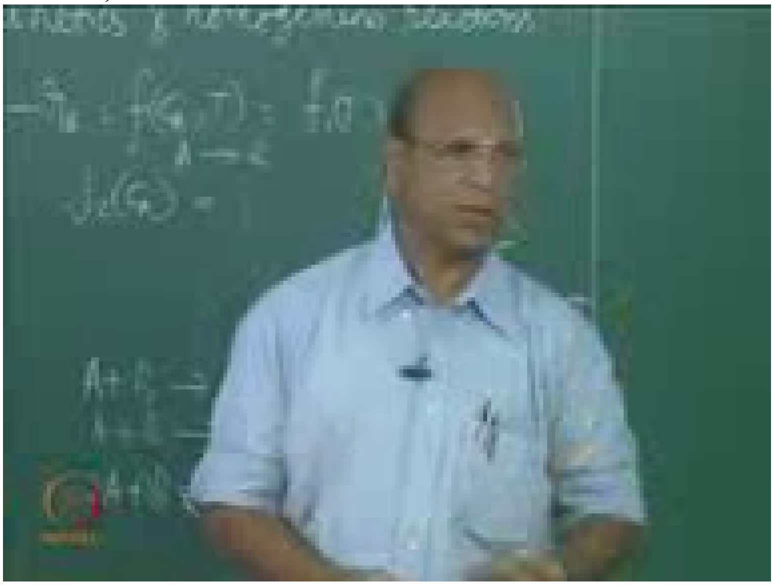

3 tablets if you take. For how many people, multiply and you will know what is the F A naught. I mean F A naught means again you, that is the product. You have to convert into stoichiometrically what is the input and then finally you will get, so that is also no problem. Problem is here only.

That is why in the kinetics and you do not have any theory for all these things, you have only experiments, right? So what do you do, generally in experiment what we do is, for example if I take this equation A plus B, right and then A plus B we will mix together in a, any reactor can be used in fact, right?

Let us say simplest is batch reactor, both you put and at time t equal to zero you start the reaction, when you put itself. The temperature and all that if you maintain and suddenly you pour these two reactants at 100 degrees for example, so the reaction starts and take the samples at every time, Ok. That timings and all that, for every reaction you have to determine.

If someone is taking that reaction time, you know that sampling time in 1 minute in one reaction does not mean that you know everyone should use only 1 minute in the world. If you go to biochemical reaction, you have to use 1 day 1 sample. Because the microorganisms like us so lazy, they also do not work, Ok. So that is why, I think you know it may take.

That is why the proper sampling time always depends on the type of reaction and you do not know how fast it is, how slow it is, so that is why in the beginning it is trial and error. You take 1 minute, 1 minute, 1 minute, you will get may be only 1 percent conversion, Ok. That means that 10 minutes is not sufficient.

Then you take 5 minutes, 5 minutes, 5 minutes, 5 minutes 10 samples, it goes to 1 hour, right 50 minutes, Ok. So then still if the conversion is not, conversion means you know the amount of A, our key reactant. So how many moles have been converted, if you are able to find out. If it is not, again 80 percent, 90 percent conversion, again you have to change the samples, sample timing.

So that is why it is not that easy. In fact in laboratories we are spoiling your brain.

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Because in laboratory also we say that everything is given. Spoon feeding. Indians are very good in

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spoon feeding. Correct. It starts with our L K G onwards. Not even L K G, from the time they stop taking mother's milk no, from then onwards we take a spoon and feed in the mouth. Correct no? We mix Farex, Farex

(Professor – student conversation starts)

Student: Cerelac

Professor: You can find 100, I say. I know only Farex, I think. Which baby is that?

Student: Cerelac baby

Student: (laugh)

Professor: Cerelac baby, I thought you said Shaka laka baby.

Student: (laugh)

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Professor: There is a song you know, Shaka laka baby

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or something is there.

Student: (laugh)

Professor: What is that movie?

Student: Mudhalvan

Professor: Yeah right, right Mudhalvan, Mudhalvan. I think that Farex, there is a competition also, that baby food and all that? Yes. This is a dictionary I opened now.

Student: (laugh)

Professor: Encyclopedia, yes tell me. Farex baby, some competitions are there

Student: Forex means that is a trading platform, investment trading platform.

Professor: But that is for only baby food mainly.

Student: Forex investment.

Professor: No, it is a brand name. No, not baby food? Yeah, Farex baby food is there. I think some other food also is there.

Student: Nan, Sir like...

Professor: What is that, Nan?

Student: Nan

Professor: N a n

Student: N a n.

Professor: This I have not seen. Ok. So like that you know, why did I tell that?

Student: (laugh)

Professor: Spoon feeding, yeah true (laugh) That we remember. Because that is the only thing we remember.

(Professor – student conversation ends)

So that is why we are spoon feeding too much in the laboratory, you know. Start with, these two reactants you take, and reactant is already given, 1 liter or something, and then we specify, take A so much amount, B so much amount, maintain this temperature, everything we are telling.

I think you know anyone can do. You need not have a B Tech degree to do that, the way we are telling in the laboratory, correct no? Every instruction is given. So whoever is able to read English, they can conduct that experiment.

That is why I was also telling my students you know, the difference between mechanic and you is, mechanic also takes the reading. He can, beautifully he can take the reading. Right. If you are able to, if you are not able to use your brain. But the student's brain comes only when he is trying to interpret the results.

Ok, something is increasing. Mechanic cannot tell, of course mechanic if he has eyes he can also say that when you move this direction this is also increasing. But why increasing is very important. That is where the student knowledge comes, right? That is one part.

And without mechanic if I ask them, Ok you construct your own column. Like I am telling you in this batch reactor also, you take your own batch reactor and then you know, you have to decide now which, batch reactor means it can vary from zero volume to infinity volume. Theoretically speaking, correct no? Yeah, which volume you choose? Right?

And also A and B what are the quantities you use? What are the temperatures you use? Correct no? And when you are taking sample, what do you do with that sample? You drink or what you do? You have to analyze. So what kind of analysis you use? Right

Is it titrimetric analysis or is it only titrimetry, you know all the time or you can also go for some color remove, color change, if there is a color developing during the reaction? The moment you put A and B, both are may be white color or may be water color then when the reaction is starting so then it may become slightly red and more red and more red and that intensity of the red is increasing.

If you are able to characterize that red through some other probe, some other mechanism of measuring so then with time how the color is changing. Now that color is the function of concentrations, correct no? Because reaction is taking place, concentration is depleting. Or product concentration is increasing. All this you have to think. Why?

It need not be color. You know when p H is continuously changing during reaction; p H measurement can be done. Conductivity, thermal conductivity, you put the thermal conductivity probe inside and then 1 minute, 2 minutes, 3 minutes, 4 minutes you do not have to even take sample. Conductivity measurement, conductivity probe directly connect it to computer.

That will record with time the moment you switch on the computer and start the reaction and you know, switch on and the data transfer there, so continuously it is increasing or decreasing whatever you are measuring, so conductivity. Now before, Ok at least before doing or after doing this conductivity measurement, you should have a relationship between what are the number of moles and what is the conductivity.

That is what we call the calibration chart. You have heard of it, no?

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Calibration chart. So that calibration you have to make in the beginning itself. So that means,

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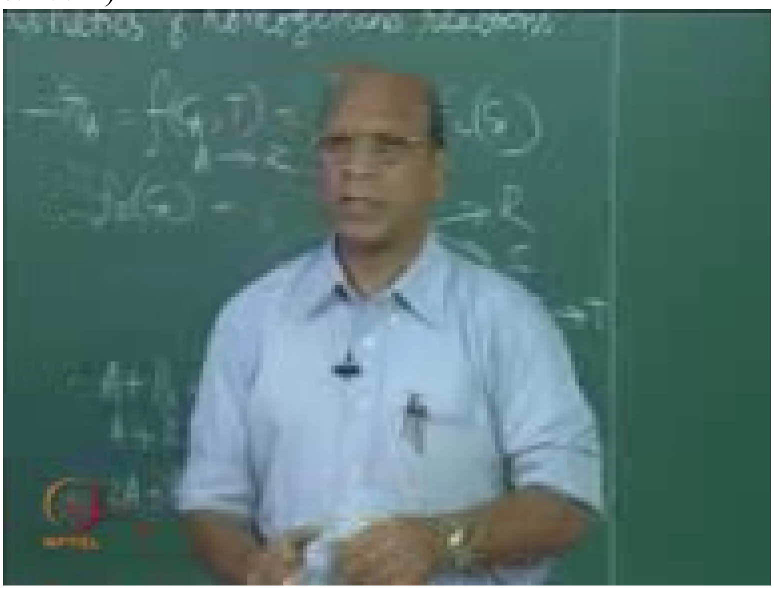

one mole means this is the conductivity. 1 point 5 mole means this is conductivity. 2 moles means this is conductivity. I am talking of moles of 1 reactant, key reactant, Ok.

So that is why there are so many methods, so many methods. That is why foreign education is much, much better than our education. It is not that much spoon feeding. In B Tech level I think, they are also not that good but at particularly P G level, you have to learn everything on your own, everything on your own. That is why they also give less number of courses and more work.

I think now, that is why we have also reduced now, we have only 5 courses no? Yeah, of course for M S P h D scholars it is only 1 or 2. So that is why number of courses also now we are reducing. In fact our department started reducing. We wanted even 4, so that you know, you take less number of courses but give more work for them to do. Then only you will learn.

So that is why, I tell you this is real hell. And I will come back to this one; you know anything I missed apart from this kind of reactions? Any other kind is there? These are all homogenous, either gas-gas or liquid-liquid, Ok, either gas-gas or liquid-liquid, right? Yeah, so now, heterogeneous I will go. But what about this one? Any other thing I missed? Of course I

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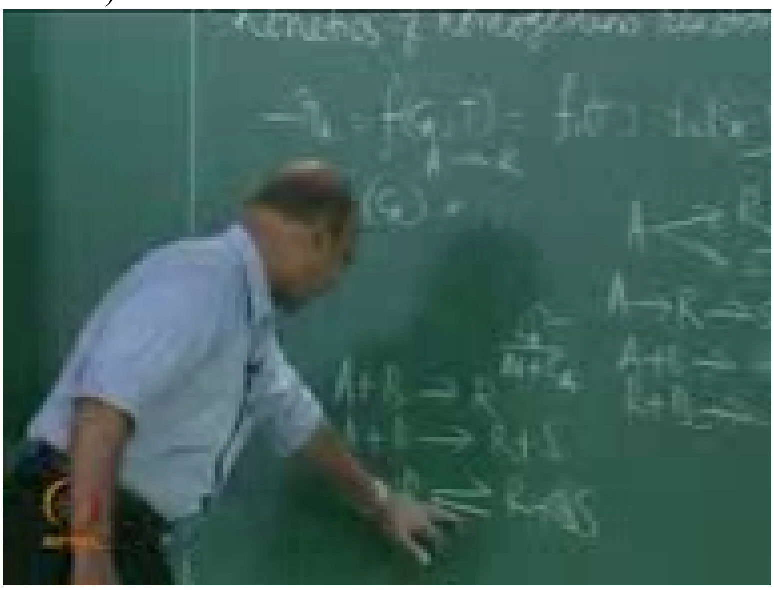

also covered reversible reactions.

Reversible reactions can also be, of course very simple type.

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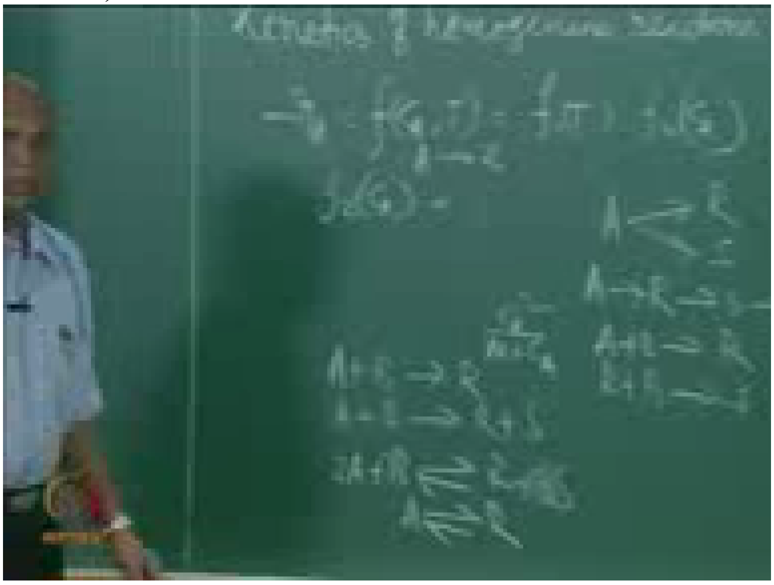

These are all professor's favorite 0:16:57.5, A going to R and A going to R reversible. That is all. We do not go beyond that most of the time. So all other things are given to you to do. Yeah it is right.

Auto catalytic reaction which normally we write, when R is the product, R plus R, Ok. This R is the product. But unless you have some product in the beginning, initially

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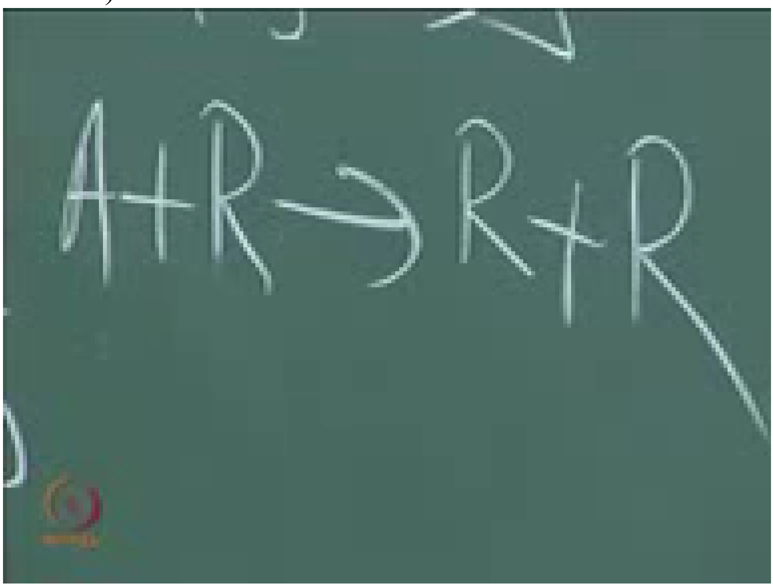

this reaction will not start. And otherwise you can deliberately add and it seems there are many reactions particularly in organic reactions where you wait for some time, somehow 1 or 2 molecules of R will form, Ok and then onwards it will auto-catalyze the thing, the product. So that is also another type.

So like that we have all kinds. And unfortunately what your job is, that every time you look at a reaction rate, you cannot tell what is the order of the reaction. That is what is the answer. If I tell you that A plus B going to R, what is the order of reaction, right? You say Sir, we cannot tell unless you tell me whether it is elementary or not.

If it is not elementary and if I say I do not know whether it is elementary or not, then only possibility is doing experiment, Ok. So that I will come back again. Because I think heterogeneous systems next semester only I will do it, but to give you a flavor, because in my diagram, that entering, leaving and kinetics, contacting in that diagram, there is physical kinetics and also chemical kinetics. That you remember.

So I think now itself it is better to have some idea about what is the meaning of this physical kinetics. That will come only for heterogeneous systems. So that is why I will give one or two examples of simple equations how do you develop for heterogeneous systems and I will also explain the, how our brain has to use, I mean to be used for developing these rate equations.

Homogenous it is very simple. I do not have to imagine much. Why? I take A and B. I stir it and by my definition of homogenous, these molecules will be beautifully mixing together, at molecular level itself they are mixing very well. On the top of it I am also putting another extra stirrer and then mixing. If it is gas phase, much easier to mix also. Even without mixing also you have the good mixing.

That means in homogenous, instead of saying it is one phase, what you have to say is the molecules are available for reaction. If it is A going to R, you do not need any other molecule. All A molecules are simply decomposing, provided if you have that sufficient collision, sufficient conditions inside the reaction to take place.

Those are all called decomposition reactions. A decomposing to, this I have not there, Ok, here also I can tell A decomposing but reversibly decomposing

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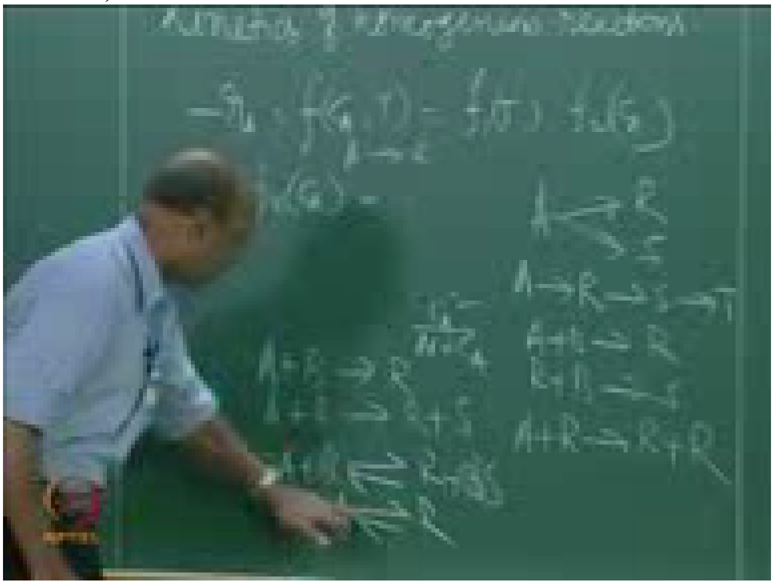

to R. Our imagination is that even these A A molecules will come, because all these things are randomly moving. Even in liquids also molecules move, right? So when they are moving and then colliding with each other and when they attain sufficient activation energy, right, that is why when you increase the temperature, what will happen?

Number of collisions will be

(Professor – student conversation starts)
Student: More
Professor: Yeah increasing. More rapidly they are going and colliding, right?
(Professor – student conversation ends)

Activation energy will not change but quickly that activation levels are reached quickly because of the high energy in the molecules now, because at high temperatures. So those things will come together, collide and then reactions will happen. That is what our imagination, good, so if I have A plus B also same thing, 2 molecules will come and all that.

Other than that I do not have to think. But only thing is, is there A molecule by the side of B? Is there a B molecule by the side of A? So that it need not search. Ok. So that is homogenous reaction. I do not have to think much.

Now the moment I go to heterogeneous reactions, heterogeneous reactions,

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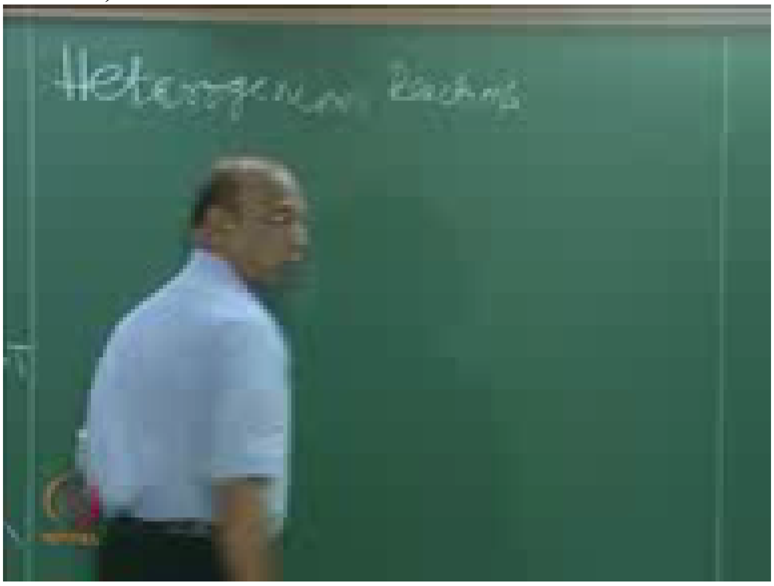

we have given already the classifications, right? So it can be gas-liquid, gas-solid, liquid-liquid, liquid-solid, gas-liquid-solid, solid-solid. These are the 5, 6 categories. You cannot have more than that. What are the things? Start with g-l.

(Professor – student conversation starts)

Student: Gas-gas

Professor: Gas-liquid, gas solid

Student: Liquid solid

Professor: Liquid solid yeah

Student: Solid solid

Professor: Yeah, liquid-liquid.

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And gas-liquid---

Student: Solid.

Professor: These are the things. These are the possibilities.

(Professor – student conversation ends)

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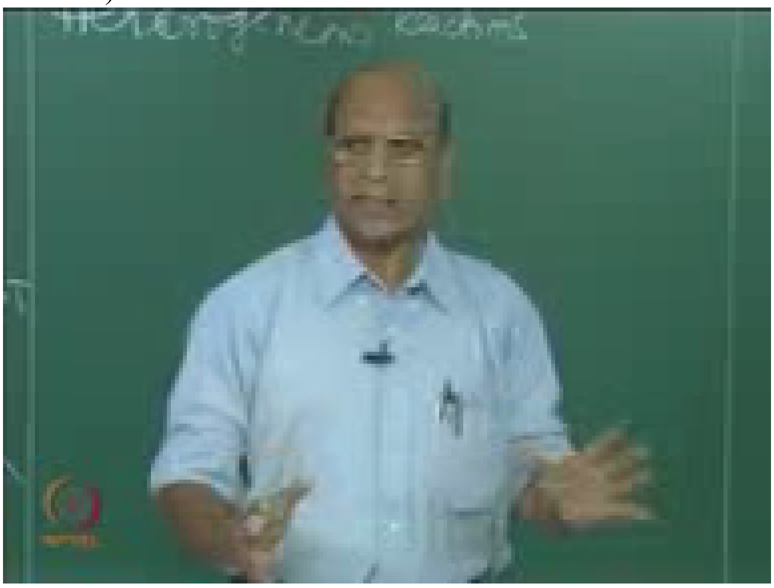

That means there is one reactant, if I take, yeah the simplest cases I take. The simplest case is gas-solid. It is not only the simplest but more

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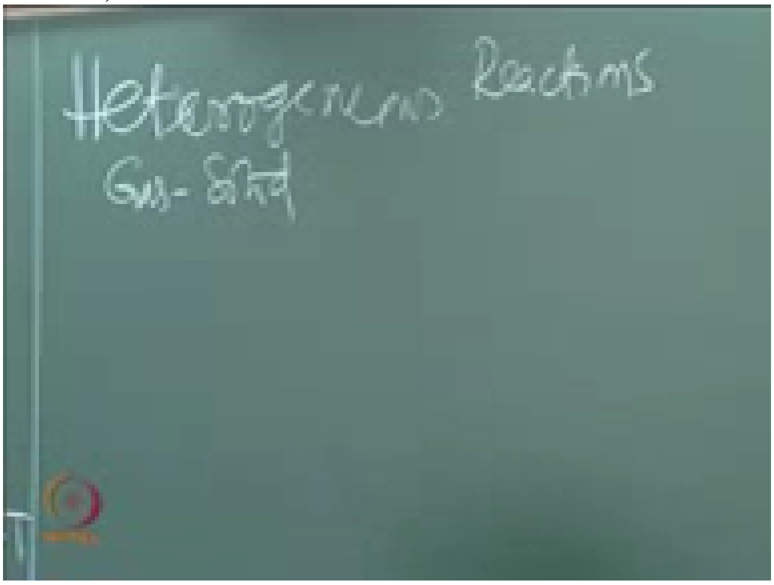

number of gas solid reactions we can see in chemical engineering problems. Ok, more number of gas solid reactions. And these gas solid reactions again can be catalytic or noncatalytic. OK,

One example of catalytic quickly? One example

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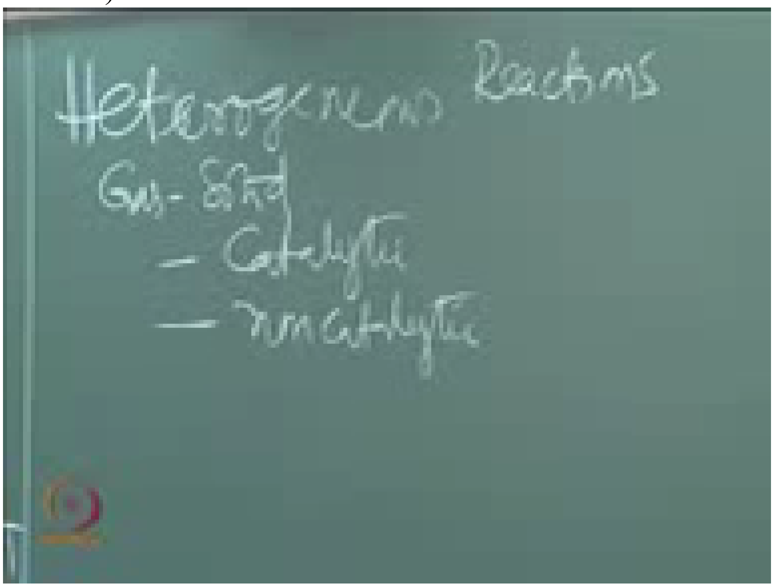

of catalytic reaction?

(Professor – student conversation starts)

Student: Ammonia,

Professor: Yes? Ammonia synthesis, Shraddha, you are Shraddha no? Yeah tell me.

Student: Ammonia synthesis

Professor: Ammonia synthesis, what is the catalyst?

Student: Iron

Professor: Iron, OK,

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any other one? Most of the time we know only 2 reactions.

Student: Sulphur dioxide.

Professor: Yes, sulphur dioxide to sulphur trioxide. But what is catalyst there?

Student: Vanadium pentoxide.

Professor: Please remember, at least

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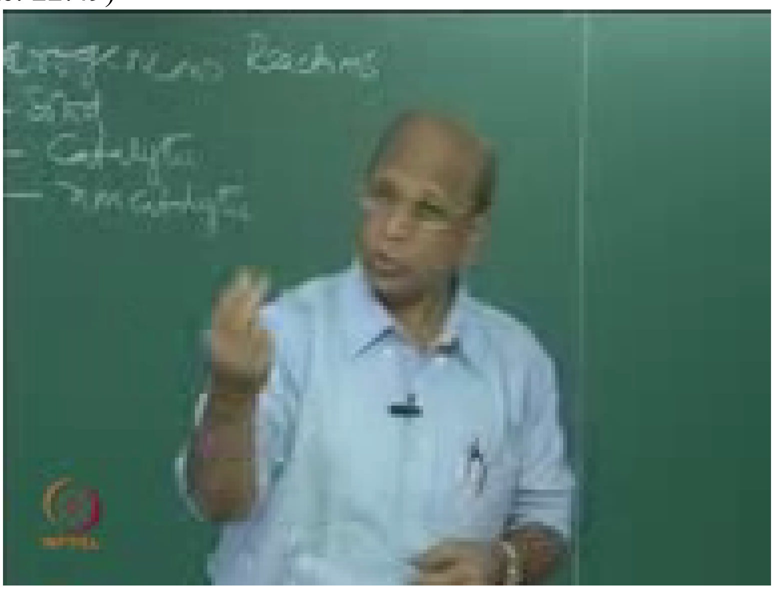

2 reactions you remember. Right, we designed so many reactions but I think at least 2 catalytic reactions, when someone asks you what are the catalytical reactions you can tell. Non-catalytic reactions?

Student: Coal

Professor: Coal combustion, coal gasification Ok and other reaction, other than coal?

Student: Rusting

Professor: No, rusting is Ok, yeah. I think rusting we do not have to do anything; Ok it will rust anyway (laugh). So that is not the one. Other than rusting, how do you make iron from iron ore?

Student: 0:23:30.5 Roasting

Professor: You see, you see how bad we are, you know in knowing things. Shahid, where did you study, at AC Tech?

(Refer Slide Time: 23:42)

Doesn't matter, I am not blaming you, blaming institute but I am blaming our wonderful education system which we developed in this country for the last 20 years. Earlier it was slightly better. Ok,

(Professor – student conversation ends)

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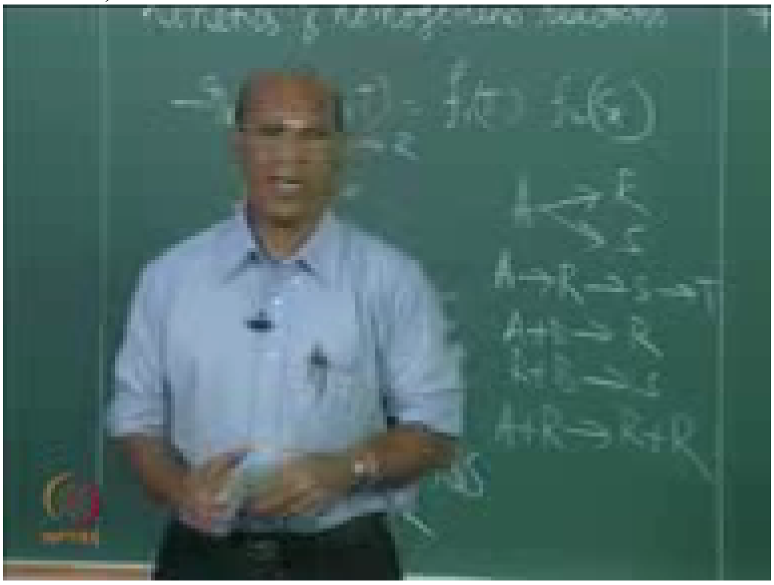

good.

So I will give you that another example because this also you have to remember. This is non-catalytic, carbon is one thing, coal plus, C plus O 2 giving you C O 2, that is the simplest one. That only I will take but we also have you know, this iron ore reduction. There are two types of ore in iron, do you remember? Magnetite and haemitite, Ok. Can you tell haemitite formula?

(Professor – student conversation starts)

Student: F e 2 O 3.

Professor: F e 2 O 3 and magnetite?

Student: F e 3 O 4,

Professor: Because H comes first so remember F 2, M comes later and remember F 3 that is how I remember. Otherwise I also get confused. Understood no, Shraddha? What did I say?

Student: (laugh)

Professor: Haemitite comes first, so that is F 2 because 2 comes before 3, yeah. So M comes later, Magnetite, F 3.

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F 3 O 4 and F e 3 O 4, and F e 2 O 3, Ok. now which one you choose? F e 2?

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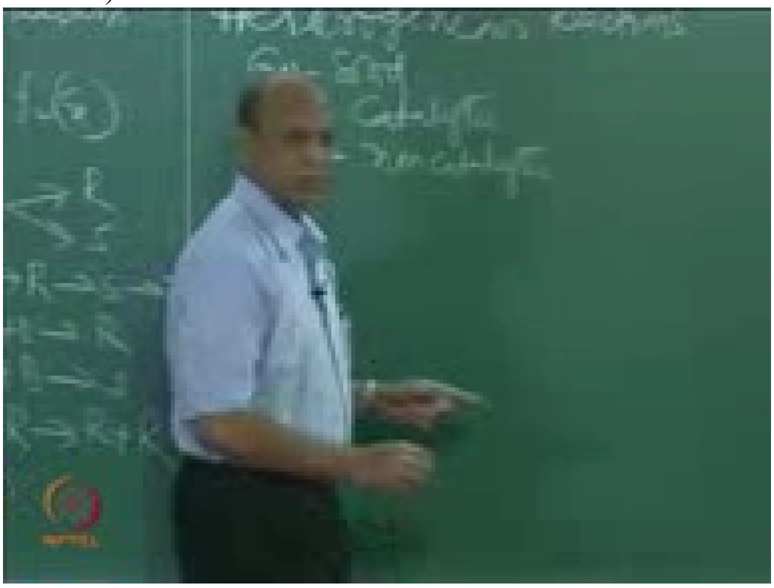

Student: F e 2.

Professor: Ok, F e 2 I choose, because democracy. F e 2 O 3, solid plus what is the gas? Oxygen? It is reduction reaction, actually

Student: C O

Professor: Yes? Hydrogen. C O also can be used. But hydrogen let us see. C O means 2 I have to write. H 2, 1 I write. So this one is F e plus H 2 0, this is gas, this is solid again, Ok, balance, this is 2, this is 3, this is 3, correct?

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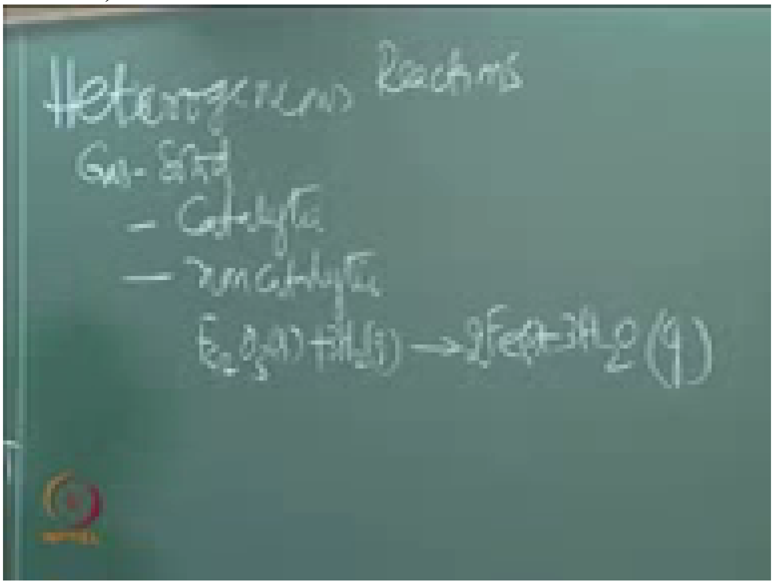

Swami? Yeah. Swami is expert in order of reactions. What is the order of this reaction? You do not know or what is that? 0:26:00.3

Student: 2 point 2 5. Elementary or non-elementary

Professor: 4 molecules

(Refer Slide Time: 26:10)

are there, can it be elementary?

Student: No, non-elementary

Professor: So yeah, it is non-elementary so that is why again we have to find the

(Refer Slide Time: 26:18)

rate equation for this means it is hell, Ok, good.

(Professor – student conversation ends)

So now this is one part. You know, first I think you know, the gas-solid reactions itself you have catalytic reactions and non-catalytic reactions. And now you have to imagine the process, in catalytic reaction, what is really happening?

That means the entire process should be in your mind. When I say catalytic reaction, your mind should go to a catalytic reactor first,

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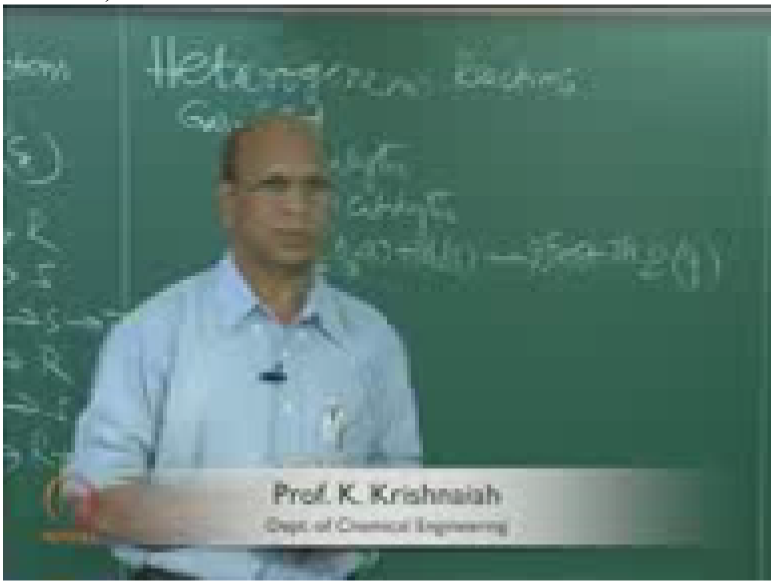

correct? You are using a catalytic reactor. What kind of catalytic reactor you can use? We have only two types, plug flow and mixed flow, right?

And when you are defining plug flow and mixed flow how many phases you have taken there? There, there earlier? Only one phase, right. Yeah that is why I told you that ideal conditions we are only discussing for homogenous systems, only one phase.

Now I have 2 phases. That is why blindly I cannot say that, you know I will take plug flow. The question comes what phase do you want to have in plug flow? Right? What phase do you want to have in plug flow? Right.

So that is why when I take catalytic

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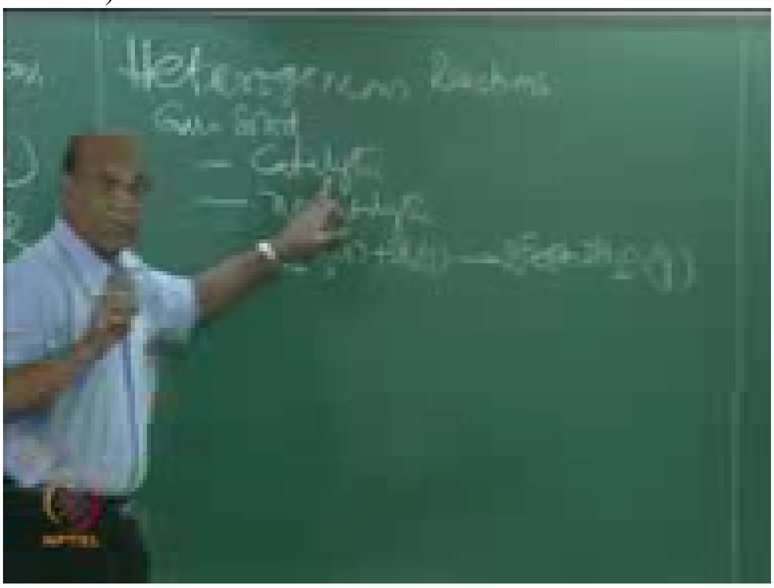

reactions which you know, which you told as iron ore, no, not iron ore, what is that, ammonia synthesis, ammonia synthesis, now I have to imagine my column. And most of the time these catalytical reactions are conducted in which reactors? Packed beds, packed bed reactors, why?

(Professor – student conversation starts)
Student: Easy contacting
Professor: What do you mean by

(Refer Slide Time: 28:08)

easy contacting? What is difficult contacting, tell me. I think that way I can ask (laugh). Why do you say it is uniform contacting? What do you mean by uniform contacting?

Student: There is 0:28:15.7

Professor: Yeah you see, 90 percent

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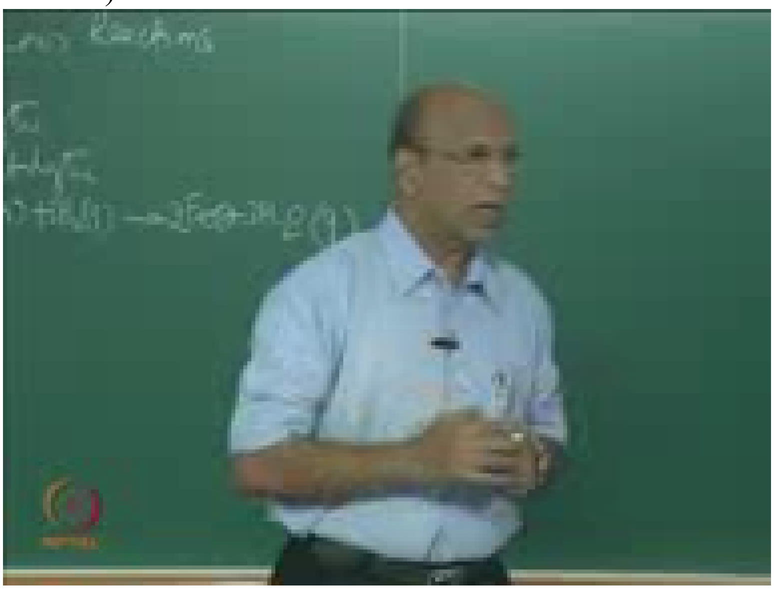

of the time what we use our words are waste words. Or otherwise we do not know the meaning of them when we are actually using them.

(Professor – student conversation ends)

I am not blaming you, including me because if you take the efficiency of people, how many words they are using in a day and what is the meaning of all these words. And if you count I can tell you 99 percent our words are meaningless. In a day you can count. You write every day, record everything, evening you analyze, Ok. That is why everything can be questioned. He said uniform. I asked what is uniform, uniform contact. Then what did you say afterwards?

(Professor – student conversation starts)

Student: 0:28:59.5

Student: (laugh)

Professor: Now he changed again. What is fixed contacting?

Student: The area is...

(Refer Slide Time: 29:05)

Professor: The area is?

Student: The area of the 0:29:08.2 is outside area, is the same.

Student: (laugh)

Professor: (laugh). No, not impressed.

(Refer Slide Time: 29:17)

Yeah anyone else, try.

(Professor – student conversation ends)

No, but I think Abdul is bold enough to say whatever he knows. Everyone of you should be like that. You should be bold enough to say whatever you know. Then it is for me to decide whether it is meaningful or no meaningful. If it is not meaningful I will tell you. Ok.

Uniform the moment you say, that means each and every particle should be exposed to the same concentration, Ok. So is it possible in a packed bed? Why it is not possible? Because it is a lengthy column. You are sending gas either from the bottom or from the top.

And the first contact is to the first particle which is staying at the top or the bottom, the way you are. So there is no uniformity. And the last particle may not see this gas for some time. So that is why. But where as if you say mixed flow, like you know, fluidized beds are called as mixed flow reactors, fluidized beds.

I hope you know what is fluidization. All the particles will be vigorously moving. Ok, you do not have to put extra stirrer. So, because gas itself will move the particles here and there, jump and through. Ok, then what you said uniform contact is better, Ok, good. So in a, I think let me, let me try now itself. I will try to explain.

Ok, this is the packed bed.

(Refer Slide Time: 30:36)

I asked you why should we use packed beds. I also told this. It is not unreasonable question because some time back I also told you these packed beds are workhorses, packed beds are workhorses of chemical industry. So memory gone? Yeah, You are not able to retain those words. I think these are nice words no, you know, workhorse.

I also told you what is the difference between workhorse and running horse. Ok I mean all those things I told you only not to forget, I say. It is only for remembering, Ok. Only for remembering I am telling. Workhorse because it is very simple to operate and it will work years and years without any problem where as fluidized bed is not that easy to operate. Why?

Inside particles are moving whereas here inside particles will not move. The name itself is packed bed. There it is fluidized bed. That means you are, you are making solids as fluid. And fluid always moves, correct no? Even water, there is no glass here, Ok. So water, unless you put in the container, the moment you break the container or put a small hole, it flows.

That is the property of the fluid. The fluid has to always flow. So that is why fluidization name came because of that reason, because you are making, otherwise solid, if chalk piece if I put will it, can it move? It cannot move. Move. Fluidization. Right now, I am making this one, you know, fluid property.

(Refer Slide Time: 32:09)

That is what in fluidization also we do. We do not do 0:32:12.5 there

(Professor – student conversation starts)

Student: (laugh)

Professor: But I think we use a compressor

Student: (laugh)

Professor: That will be very good. First all research scholars do that for fluidize, whoever working in fluidization do 0:32:24.2, like that.

Student: (laugh)

Professor: I think by evening, their face volume will be double. Ok. Yeah all these things you know, these will go up. Ok anyway.

(Professor – student conversation ends)

So that is what is fluidization, right? So that is why, and when the particles are moving and because of the movement sometimes even the sides of the reactor will be eroded, you know corrosion, erosion. Ok, slowly eroded means all the surface slowly depleted so all these things may happen. So that is very difficult to operate.

Whereas this is not difficult to operate. What we simply do is we pack all the particles, not so big particles, there is a ratio also. Ok, then

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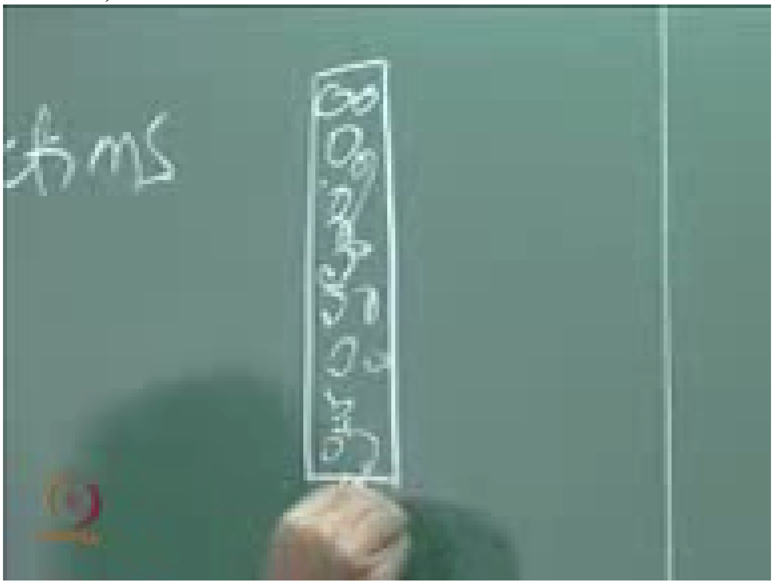

this is, for example when I am talking about ammonia, N 2 H 2 both are entering and this is F e, F e cat, catalyst, right and then you have here some N H 3, and it is a reversible reaction, you remember that, no? N 2 plus H 2 giving you N H 3 is a reversible reaction.

So you may not have 100 percent conversion. So that is why some N 2, some H 2 will be there, so those things also I have to write, N 2, H 2 all that will be there. And now when I want to develop the kinetic expression for this heterogeneous system, this is the system which we have

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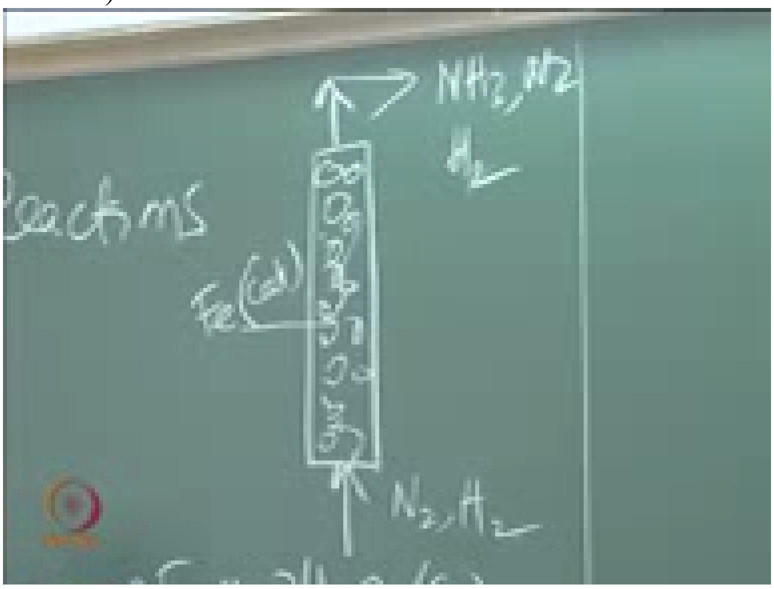

to imagine first.

Then my focus has to go to one particle, somewhere here. That one particle I will take it out. So when I take that one particle out, this is the one, that particle out, and now I have to imagine, around the particle, you see all this is imagination, all this is only in your mind. Ok, you close your eyes. All the steps automatically come.

That is what we say, physics of the problem, physical phenomena of the problem. What is really happening? Unless you understand this physics what is really

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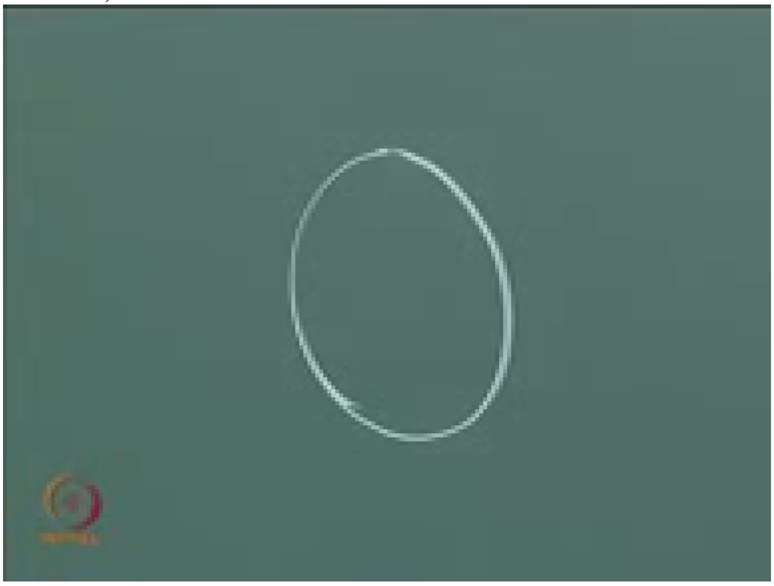

happening, the phenomena inside, you can never write an equation. If you write the equation without knowing the phenomena, there is no use of that equation. There is no meaning for that equation.

That is why every time, please remember. I think next time you will do transport phenomena also. Because the phenomena should be understood first. And then only you start writing the equation. So first of all you have to imagine the entire equipment first. Ok. Packed bed is this.

I am not telling you what is packed bed and all that because you have already done that 2 course, you know, in B Tech level itself you should have known what is packed bed. Even otherwise packed bed is easy to imagine because packed bed is nothing but a cylindrical column with a distributor at the bottom and then top also another distributor. You pack all the solids in between so that they should not move.

And student cannot imagine this distributor plate. He thinks that it is simply, because I have not drawn here distributor plate, right, so that is why

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he thinks that you know he can have solids just in the column somehow floating, Ok, without moving, like floating mountains, Ok. So like that you may be imagining but distributed design is also very, very, very important. In fact that is one of the crucial designs in packed bed operation, you know the distributor.

Otherwise if you put completely a plate like this, yeah, this is a plate, a circular plate,

(Refer Slide Time: 35:56)

and try to send N 2 through this or ammonia hydrogen through this, can we send? You cannot. That is why if you want to send, you should have hole. And what is the size of the hole? If you put 1 micron holes or may be 1 nanometer holes then what will happen?

(Professor – student conversation starts)

Student: Still it will not enter.

Professor: Why is it not possible?

Student: Possible sir, but flow rate will not be...

Professor: Why flow rate will not go? I can also use very, very big compressors and then push it. Flow rate also I can maintain

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Student: Pressure drop

Professor: Yeah, that is the one. As engineer your mind

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should go to the pressure drop first. Why?

(Professor – student conversation ends)

Because you have to buy such a big compressor, all the money whatever you get you are about to get as profit will go to only design of compressor. Ok. So that is why you cannot do anything. You do not get any profit when you start a company.

So that is why the distributed design also has some parameters where you have to take what is the diameter of the hole, Ok. How much is the free area, all this you have done without knowing, you know without knowing this, you have also designed distillation columns where distillation columns have perforated plates.

Not only distillation, adsorption columns also you have done? Ok. Yeah, adsorption columns also because you are bubbling the liquid throughout, sorry you are bubbling the gas through the liquid. So how do you bubble, unless you have the perforated plate? So that is why, you know we never forget.

I know, some of us, most of us also as teachers, we also never point out this. I am taking more time because everything I am trying to point out at least once in your life, Ok. So that is why we are not able to run with syllabus. But I do not want to run. If I walk with syllabus, that is more than enough for me, right? So that is why, this also is very important. All this, and on the top also, right?

In fact in R E C Warangal at that time, it was R E C Warangal, so when we were doing the laboratory there was a mechanic. So some pump was not working in fluid mechanics lab. The gasket has gone. You know what is gasket? Between two flanges, Gopinath you know what is gasket?

Really? Ok. So when you are joining two pipes, you know what are flanges? Flanges also you do not know? Really? Flanges. You are chemistry or chemical engineering? Ah chemical engineering. You know what is flange? Oh my God!

Ok how do you join these two pipes? I have one pipe here, one pipe here, how do I join? Do not tell me you are going to weld.

(Professor – student conversation starts)

Student: (laugh)

Professor: Ok, that is one if it is permanent.

(Refer Slide Time: 38:42)

Student: Nut and bolt.

Professor: It is not permanent. Whenever I want I have to open and then again clean it

(Refer Slide Time: 38:46)

and again join it. So what you will you do?

Student: One end...

Professor: Ok I have two pipes, where do I put nut and bolt here?

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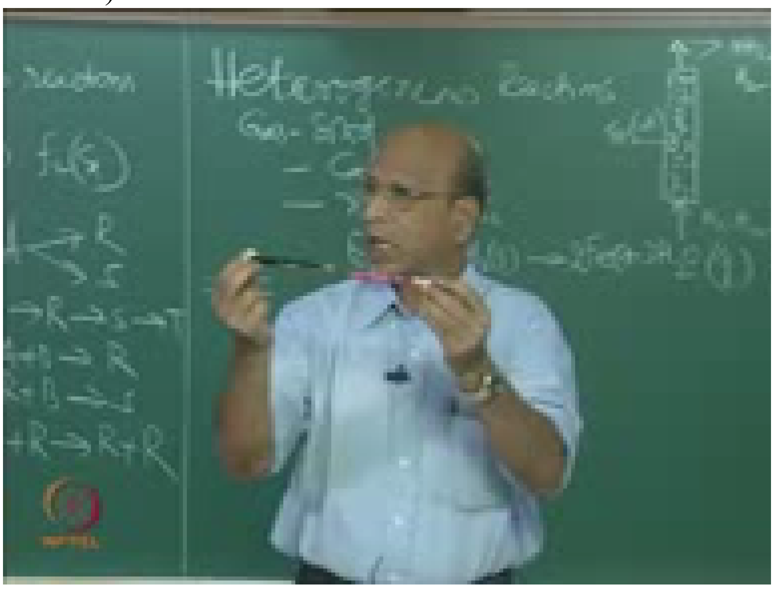

Student: 0:38:54.4

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Professor: Yes, around this I should have a flange, Ok, so that means it should be something like this, Ok and this side also exactly same thing, and this is the pipe,

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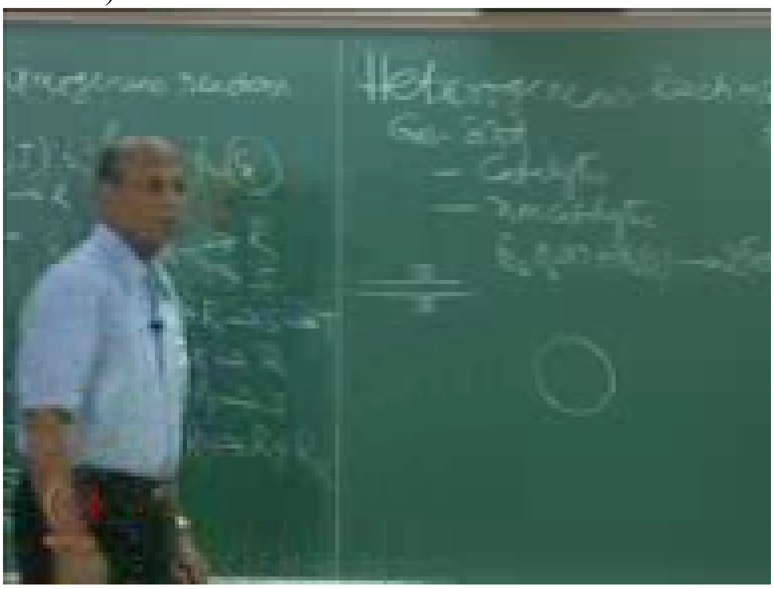

Ok and when I look in this direction, at least once then it will be like this, this is equal to this. Ok.

(Professor – student conversation ends)

Then you will have, yeah

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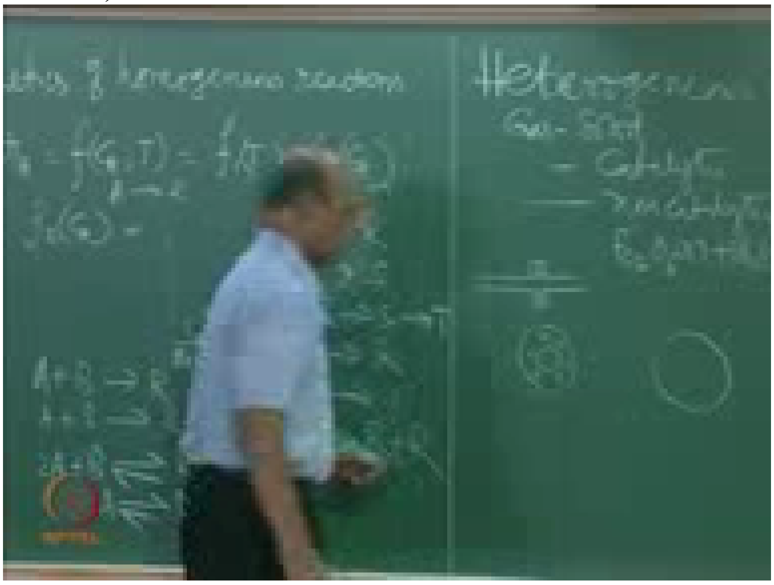

normally there are 6 or 8 or 12 I will put there, positive, what is that, yeah even numbers, so that when you are tightening it is uniform tightening will come there, so that you will do and then you will also have this side also similar type, this is one like this,

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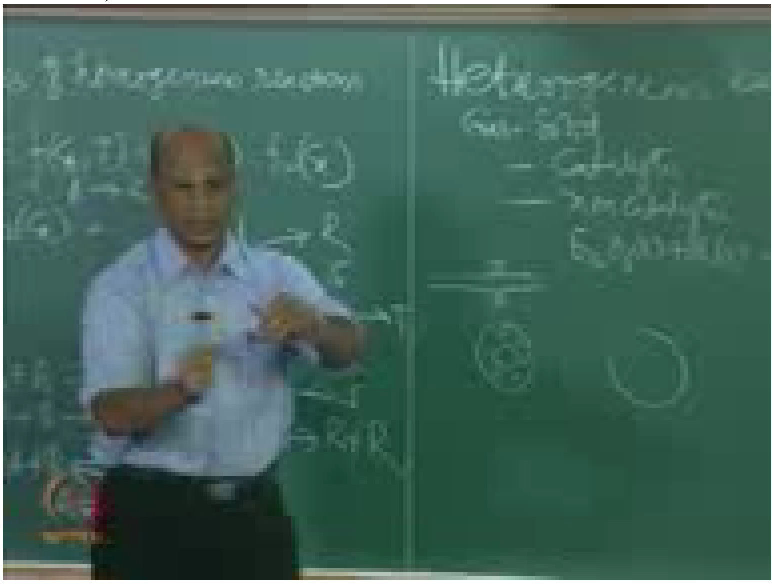

another one here, join these two and then tighten nut and bolt, Ok?

But this is metal and this is metal.

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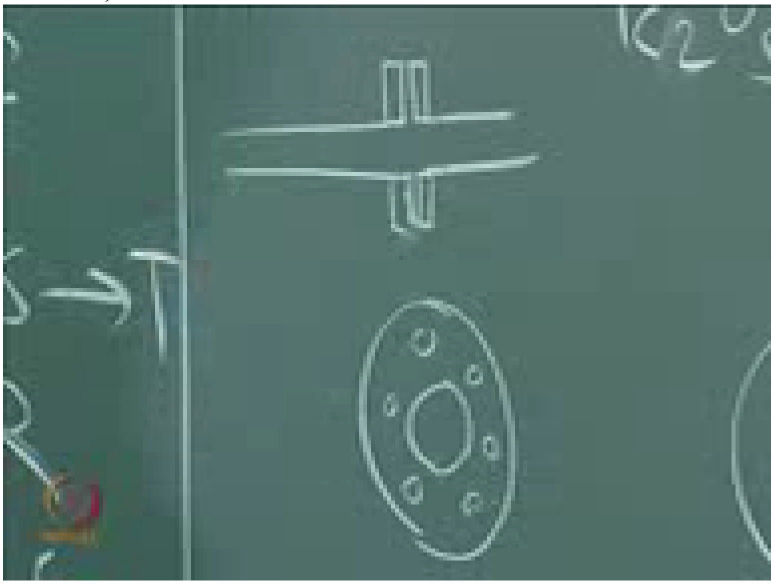

So when I just tighten without putting anything inside, that metal metal contact is not perfect. So that is why it leaks. So what do you do now? You put a gasket. That gasket is normally is a rubber, neoprene rubber or so where it is having slight elasticity so that it can be a little bit compressed, right and then you also should have, because you have to put in between this, right? Nut and bolt also, yeah, this nut and bolt has to go through that. So that is why you should have holes for even gasket also.

So our mechanic, what he did was he put the holes for the gasket but he did not cut this portion. So that means these were the two pipes where

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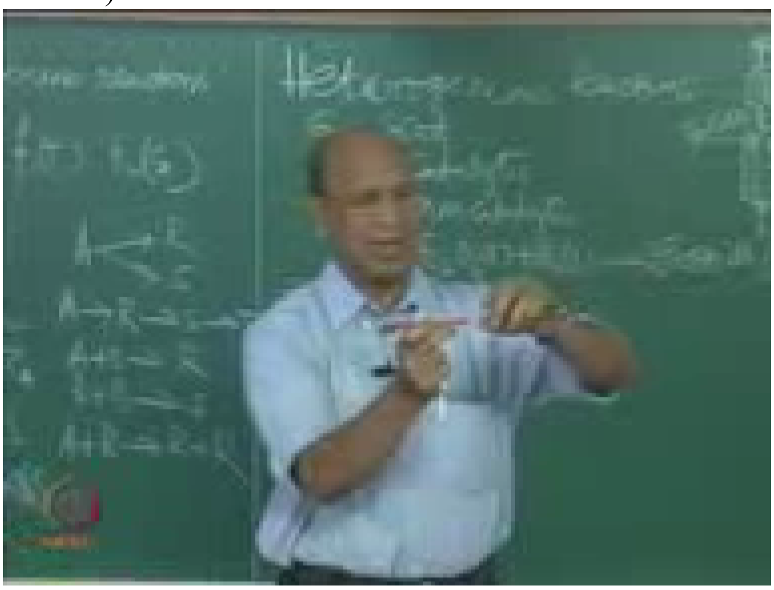

it is blocked actually. Ok, and then he started pump, no water coming. (laugh).

In fact exactly same reason, in I C I industry, Imperial Chemical Industries, they were producing ammonium phosphate. They used six tanks in series, Ok. Tank in series model also we will see later. 6 tanks they have used. So in, I think from third tank to fourth tank or so, yes third to four, may be second to third, so the gap between that you know, the gasket started leaking. So they stopped.

And without knowing that, I think some new person would have come, may be like you who just joined in the job, so without knowing what is flange, what is you know this gasket, he has put that and then tightened without any flow. So then after some time the pressure built up, some explosion happened and that is one of the worst disasters before our own disaster, Bhopal disaster.

(Professor – student conversation starts)
Student: Flixborough
Professor: Yes, Flixborough, name of that company, name of that place is Flixborough, F l e x i b o r o u g h, yeah, Flixborough, Ok. That is only, these are recorded things. You see now, those simple things we never bother to know and if you get unfortunately a job in chemical industry what will happen? Explosions only
Student: (laugh)
Professor: Ok, nothing else.
(Professor – student conversation ends)

Ok and you know, today's paper you have seen no, very tragedy. Yes, Sivakasi. And you know most of the workers are untrained people, poor fellows who are coming from the villages and then they just do not know.

They know how to, you know, crack the crackers but I think they do not know how to make the crackers. So something would have happened and so many people died. That is why this training, the thinking is very important.

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Right? Ok.So those things are also very important for us.

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Yeah, thinking whether I can continue or not. Ok.

So that is how these things will enter. Now I have to develop a rate expression means I have to know what are the, what is really happening in the column, right. So I know what is happening, means it is entering, it is coming out; somehow the reaction is taking place. These things

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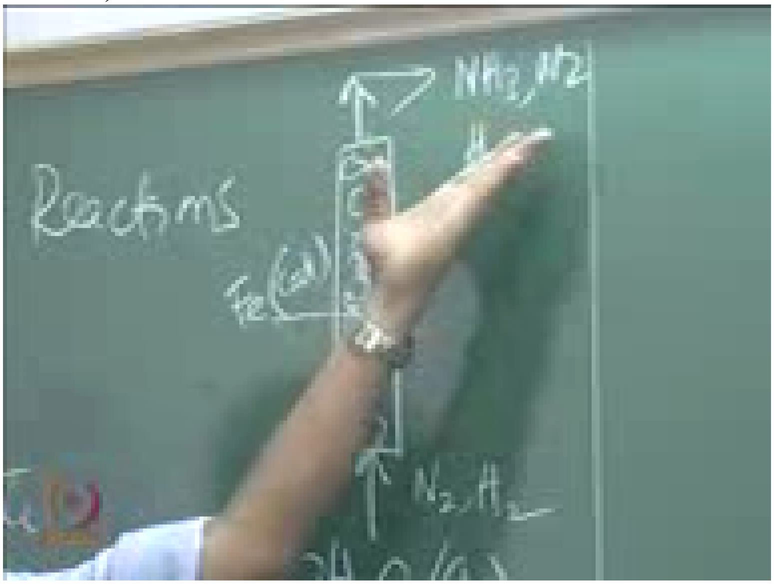

are coming. Now I have to focus a little bit, you know more intensely on a particular portion.

My portion is one particle. That is the, I will take out. So in this one particle, I know that it is a porous particle, right? And Fluid Mechanics tell me that yeah here, here also you have the particles and then you are allowing the flow to go. How the liquid flows there or how the gas flows through the packed bed? Because you have interstices between particles. We say voidage and all that, right yeah.

Then if I look at one particle here, the gas may be going like this. Then immediately there is another particle that will again switch 0:43:42.9 like this. Right, on the whole if you look, around the particle I have this flow. I have changed the direction, should have been vertical, Ok.

So this is how the flow, do not get confused. This is drawn here vertical, this is horizontal, turn it like this; that is all. Ok,

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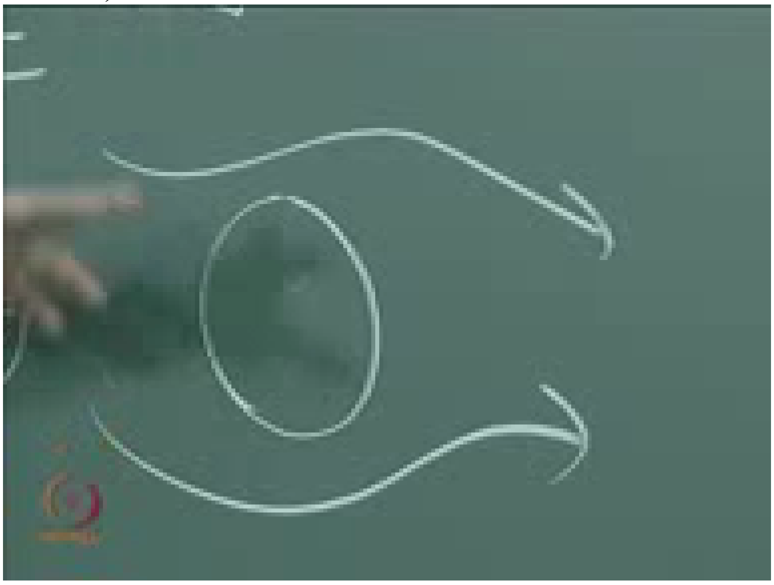

so this is the one.

And whenever you have the flow this is, let us say in the beginning, H 2 N 2, this also H 2 N 2. And we know that from fluid mechanics, this will have a film around this. Whenever you have 2 phases,

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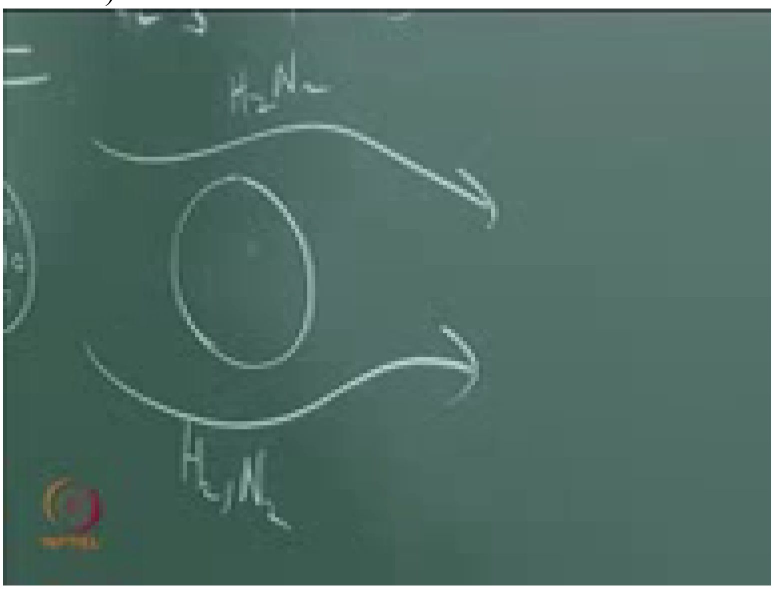

there will be interface, right and interface also will have one side one phase, another side another film. You know that is why what you call, you know, two film theory.

What is meaning of that? Same thing. Two film theory, gas film and liquid film if it is gas liquid reaction. But here we are talking about gas solid. Solid will not have a film inside. So that is why you have only fluid film outside. So this will be nicely written all the time like this. Even though this never exists like that. This is

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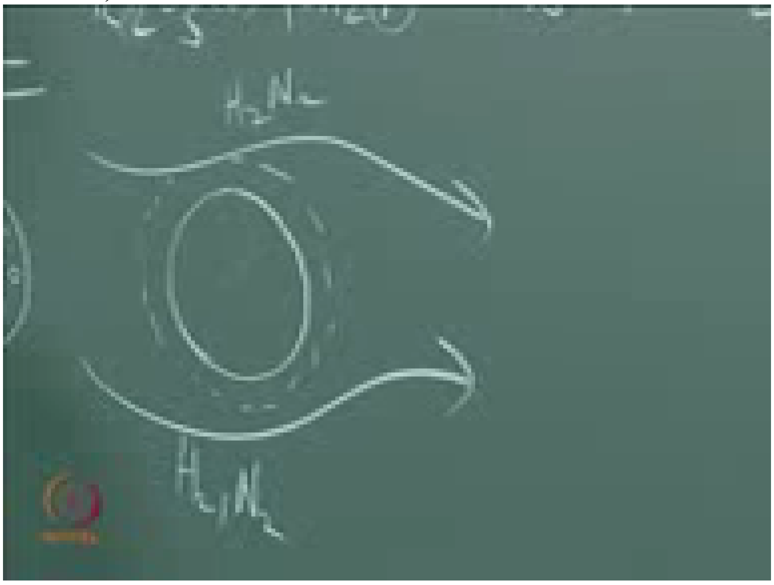

the film. Ok. This is cat, Ok, this is F e, and this is film, Ok, that is the film.

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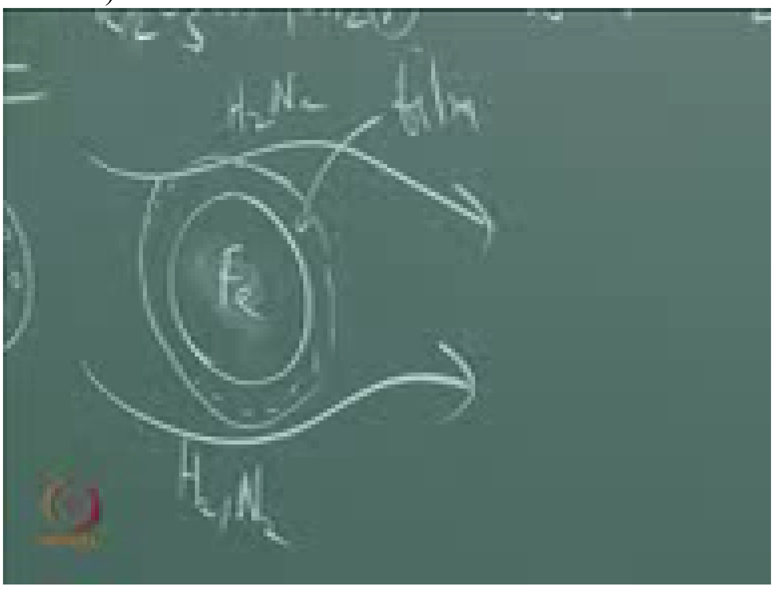

Now what are the steps that, because you have to imagine the phenomena. I have the particle. I have the fluid flowing around that, the gas flowing around that. Now what happens for the reaction to take place?

Hydrogen and nitrogen, they both have to first pass through this film, that is what is no, mass transfer, they have to be transferred through the film to reach where, to reach the surface. If it is non-porous particle, non-porous particle that means there is no pores inside then all the reaction occurs only on the surface.

So now I mean, now let us imagine that only surface reaction is possible. Then afterwards we will go inside.

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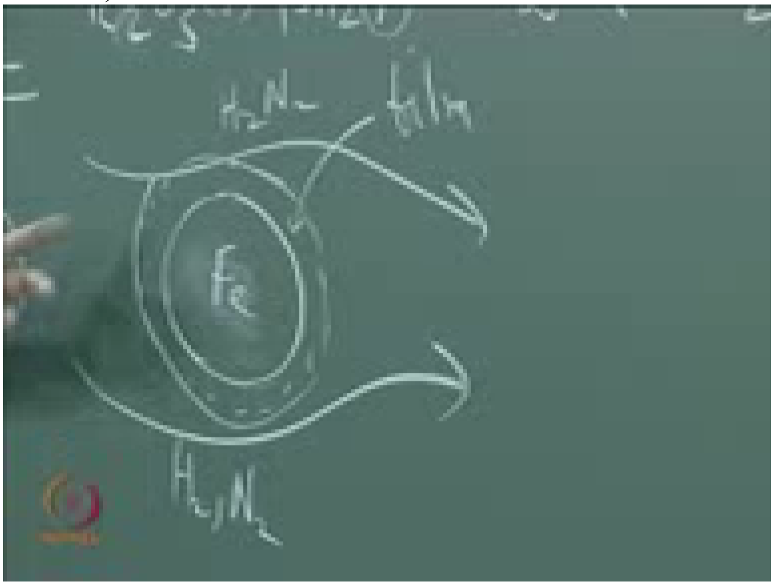

So right now I am taking only non porous F e. Solid F e, F e means 0:45:48.9 iron. So non-porous iron. So then the reaction is taking place only on the surface. Because it is a catalytic surface, reaction takes place.

The moment hydrogen and nitrogen both go there, in fact there is still more mechanism but for reaction, reaction rates to be developed we do not go to that level, at engineering level. But science level they go. Right in engineering level what I will imagine is H 2 N 2 both are going sitting side by side and then reacting and then N H3 will come out, right?

So now the concentration of N H 3 on the surface is more or outside is more? N H 3...

(Professor – student conversation starts)
Student: On the surface
Professor: Why?
Student: Because of the reaction 0:46:33.4

Professor: Exactly. That is where the production takes place so more production of N H 3 on the surface. And outside, there is no reaction, no N H 3.
(Professor – student conversation ends)

So that is why there is a gradient. I told you no, diffusion is a natural phenomena. So wherever there is concentration gradients the things will flow in that direction. Because on the surface I have more

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N H 3 and outside I have less N H 3, it will simply come out. It is now coming out through the film.

Now you see H 2 N 2 going in and, sorry yeah, H 2 N 2 going in and N H 3 coming out, that is what what we say equimolar counter diffusion. If I have same number of moles of A going in, same number of moles of B coming out. But in reality you will never have equimolar counter diffusion. It is only in our mind for simplicity of the problem.

If you have that you know that unequal moles entering and unequal moles coming out, what are the equations used? Here I can use Fick's Law, if I say equimolar counter diffusion and all that. Anyone did in transport phenomena or advanced mass transfer? Multi component diffusion. You have heard of Stefan equations?

(Professor – student conversation starts)

Student: Yes

Professor: Stefan Boltzmann or?

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Yes.

Student: Stefan equations

Professor: Stefan Boltzmann

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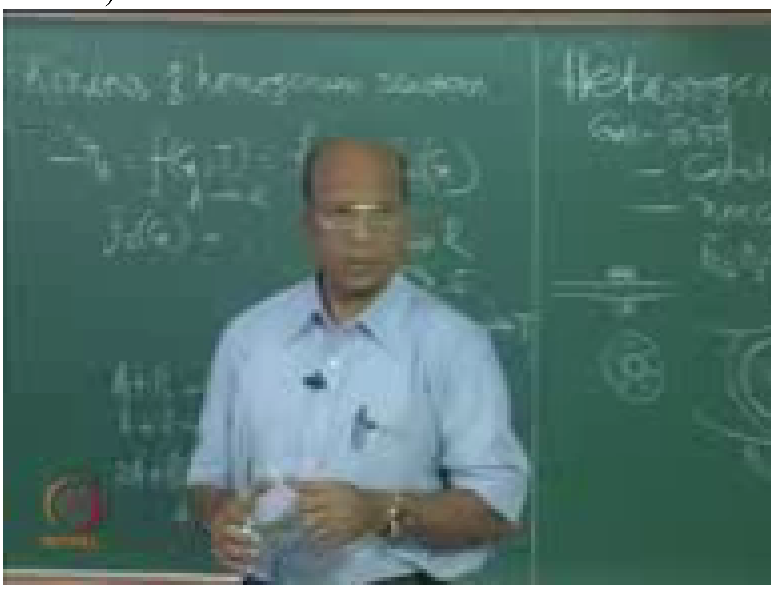

equations. No not that. For mass transfer there is, I think Stefan equation, I do not know what is the next name. Yeah. Stefan equations. I will find out, Ok. Yeah so those equations you have to use where there is used only for multi-component diffusion.

(Professor – student conversation ends)

But anytime you have used multi-component diffusion? Simplification again. So that is what. So then equimolar counter diffusion, what I am trying to say is through this, we have to now find out what is the amount of N H 2

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or H 2, sorry Ok, H 2 and N 2 entered, what is the rate

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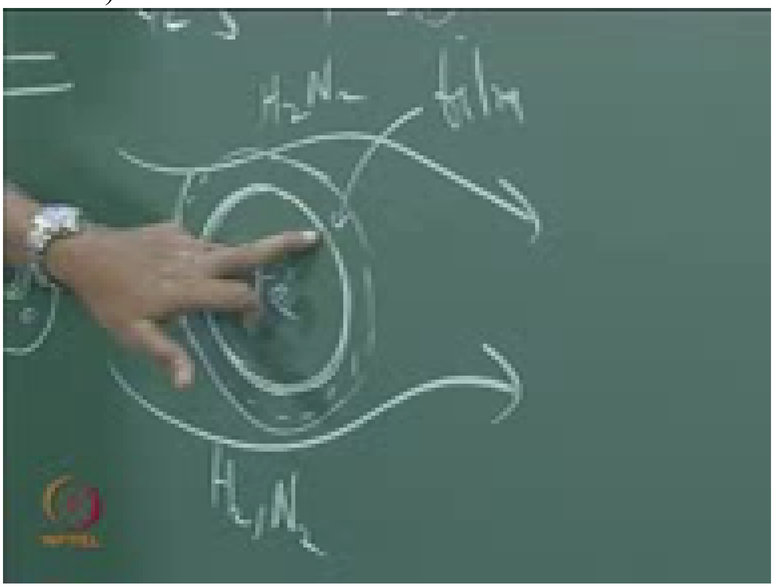

of reaction and what is the amount of N H 3 come out?

So what are the three steps now? Reactants, mass transfer of reactants through the film. Rate of reaction on the surface and yeah, rate of, we do not say desorption because desorption is on the surface but we are talking about only mass transfer through the film, Ok. We assume that the desorption, adsorption, surface reaction, all things are as surface reaction only.

So that is what my next thing. You have to go into those details again in reaction. For reaction to occur, first there should be adsorption. Then the product, not what is that, intermediate formation. Ok, then reaction, then product desorption, here product mass transfer through the film. So now

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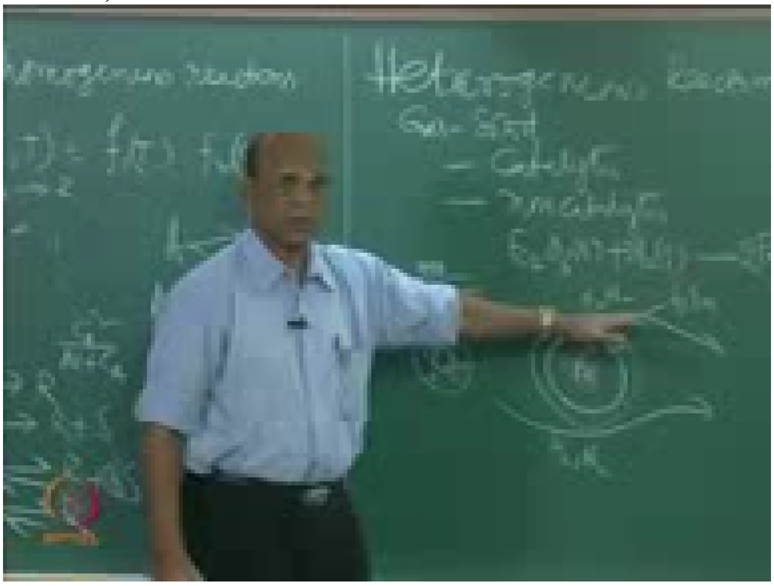

reactant mass transfer through the film, product mass transfer through the film, products and rate of reaction on the film, on the surface, sorry, on the surface.

These three must be equal under steady state conditions then only the reaction can happen. You see now, to develop the rate, how much physical phenomena I have to remember. Now the moment I know that, yes what is the mass transfer equation through the film? You have to tell me. That is the simplest one which you learnt in mass transfer first course, mass transfer course.

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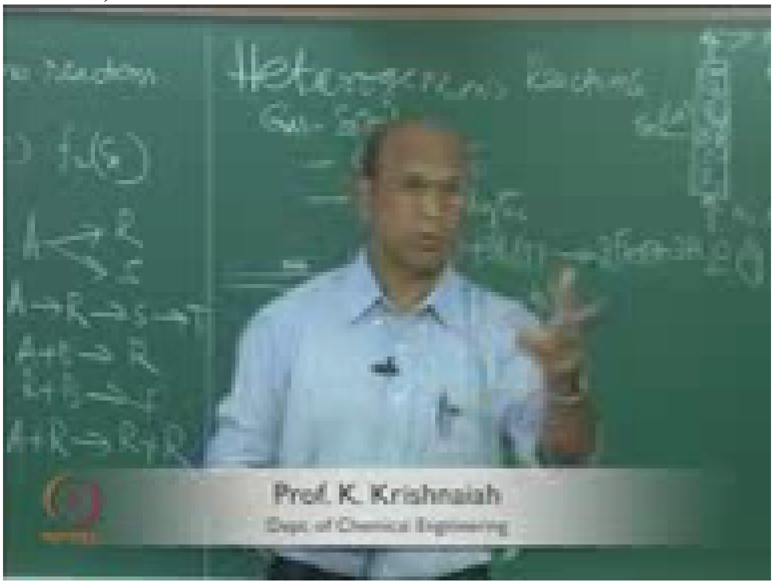

You know, first course for some of you equilibrium, equilibrium stages. Yeah anyone quickly. What is mass transfer equation, Abdul? Abdul is a bold guy. Yes, mass transfer equation.

I am not asking diffusion equation. I am asking mass transfer equation. Both are different.

(Professor – student conversation starts)

Student: 0:50:29.2

Professor: Yeah, Ok, in our so-called term N A equal to, N A is molar flux, mass transfer that one, not diffusion, Ok, that is equivalent to K into C A minus, yeah but in this case, if I say that this is C A b, this is C A s, then what is the equation?

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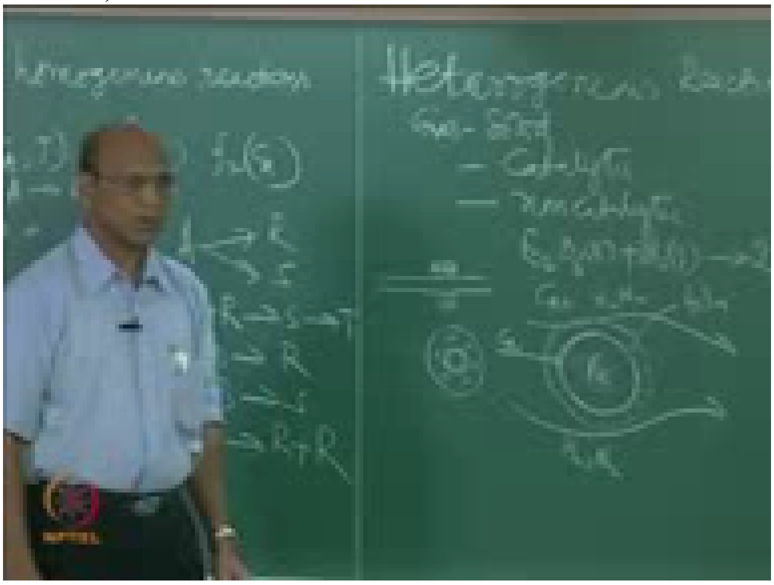

Student: 0:50:54.8

Professor: Yeah I have C B that is entering because I have to write mass transfer difference only for reactant. I cannot write reactant entering and product leaving. No. We cannot subtract one from the other.

Student: C B minus C A

Professor: Yeah this is C B minus, C A B minus C A S into k, if it is gas phase we call normally k g, this is equal to N A that is the equation. Now this equation must be

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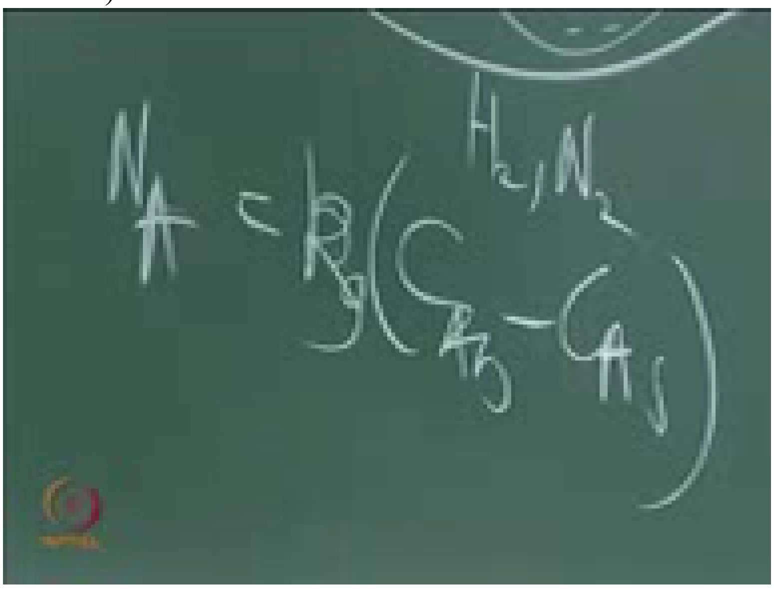

equal to rate of reaction.

(Professor – student conversation ends)

So rate of reaction, if I have first order, yeah, C A S, C A S because that is where the reaction is taking place, C A S, right and in my example, of course here actually in ammonia example it is a reversible reaction where hydrogen concentration, you know the reversible reaction also is possible.

But if I, assuming that I have irreversible reaction, irreversible first order reaction then simply it is k into C A. Otherwise it is again k into C A S nitrogen, I mean both reactants minus products. That kind of complication we are not trying to imagine now. Later you can imagine

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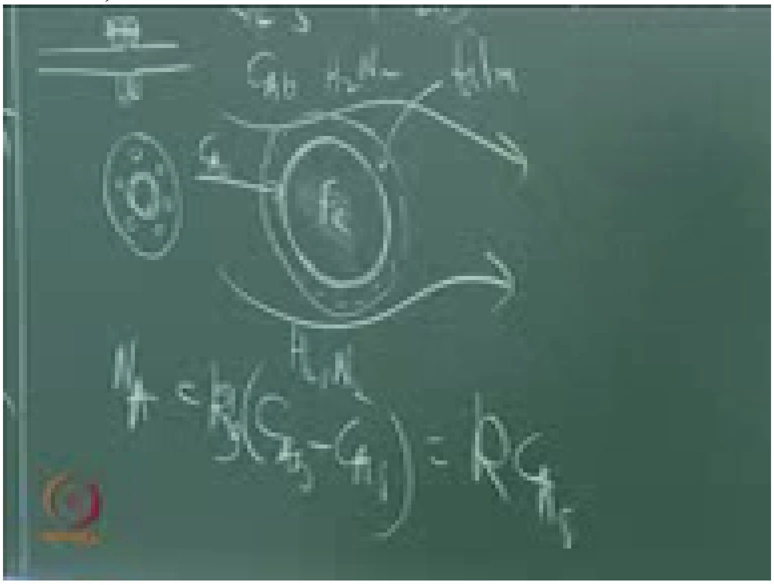

when you go to actual chemical and catalytic reactions.

So now this is the equation under steady state condition, this is what is minus r A. That is not direct, because again I have to solve for C A S and all that. I have to stop here. Oh. 0:52:22.5 minutes Ok, so I would again close this saying that, yeah C A S is not easy to take it, so that is why C A S has to be eliminated.

All that I will do tomorrow just as one example. So but my idea to you, my explanation to you is, so much I have told you, the reason is that so much thinking is required for writing this simple equation.