Advanced Chemical Reaction Engineering
Prof. H. S. Shankar
Department Of Chemical Engineering
Indian Institute Of Technology, Bombay

Lecture -09
Modeling Multiple Reactions In Soil Environment –III

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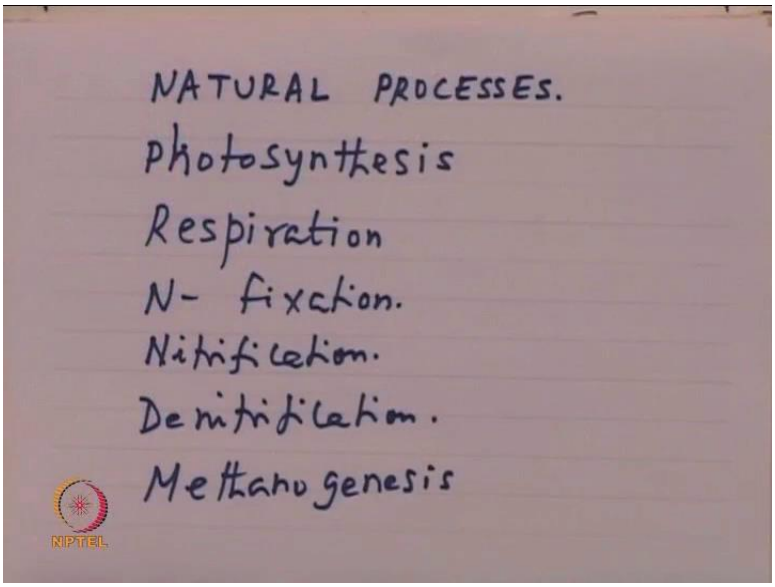

Today we want to look at, the long assignment which I had given you earlier. Now, this assignment is really a good understanding, some chemical reactions that occur in the natural environment. So, I just listed some other thing that happened, Photosynthesis Respiration, Nitrogen Fixation, Nitrification, Denitrification, Methanogenesis. These what, typically would happen in the natural environment and the context is of course, we might want to purify water, using a natural process or we might want to grow a crop using a natural processes. Whatever, meant be the case we have to deal with these many chemical reactions. So, What I have tried to do is, to give you some data so, that we can understand, how to model a very complicated reaction system.

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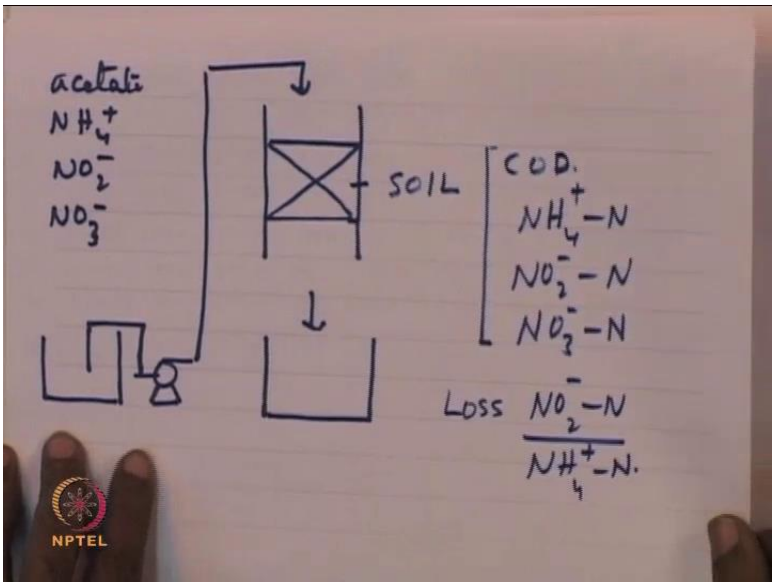

So, this is the object of the exercise; the problem that we want to solve, let me illustrate is a following; we have a natural environment in a chemical reaction equipment. Now, I the natural environment can as an example, I have taken is soil. Now, you can use this purify water, you can use soil to make produce various crops in. This experiment what has been done is, we have acetate, in the form of Sodium acetate, Ammonium source as a Ammonium fluoride, nitride source as sodium nitride and nitrate source in this particular experiment we have not used any nitrates. So, that is 0.

So, what goes into the reaction equipment is a Carbon source, Nitrogen source in the form of Ammonium chloride and Sodium nitride. So, the experiment is that, you measure all the composition of acetate, which is measured as C O D and then of ammonium is measured as NH4 plus nitrogen nitride, which is also measured and this is also measured NO3 minus plus. So, you have essentially 4 measurements on, what is going on in the reaction equipment and the postulate that, this is what happens in the natural environment that, there is change in C O D because of the chemical reaction there is a change in all these numbers. And therefore, we able to measure what happens, in the reaction equipment. Based on this, we want to say something about, what happens in the reaction equipment this is the object to the exercise

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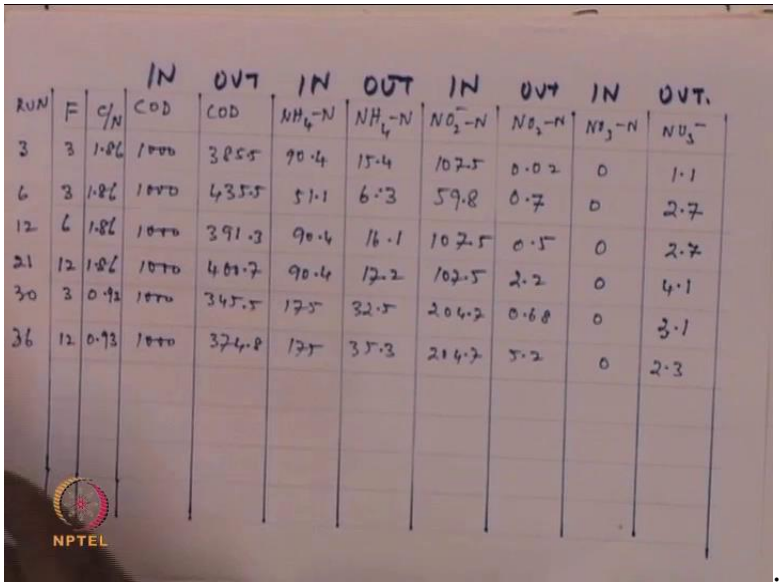

Now, I have with me some data, this I have taken from, what I have already given you. So, I have written down; I have just taken some other data, run number 3 6 12 20 1 30 and 3; where in put cod is given output cod is given, in nitrogen as ammonium is given output is given. So, this is in, let me write it here in, out, in, out, in, out, in, out. So, this is what is given. So, we want to understand, what goes on to understand, what goes on; I suggest the following model, the suggestion is the following.

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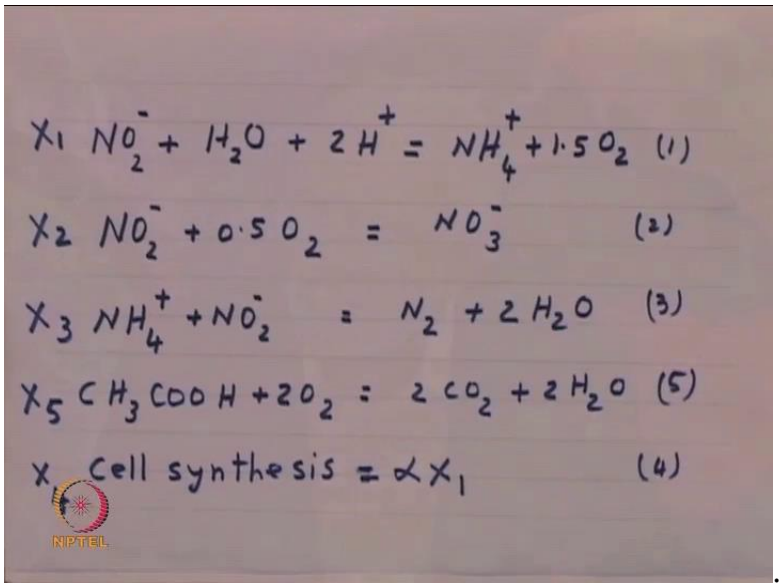

So, what we suggesting is that in the Reaction Environment that, we have Nitride get's converted to Ammonium; that means, is a reduction reaction for which energy is required, but this reaction could go the opposite as well. We do not know that, data will tell us what will happen to the reaction. NO2 minus can get oxidized form NO3 minus, then NH4 plus and NO2 minus can react to form Nitrogen and water. So, these are the 3 reactions which is postulated to take place in this soil environment of course, so, many things may happen, but what is suggested is only these 3 reactions. And the acetate which is in the form of acetic acid; I witness acetic acid it is oxidized to carbon dioxide and water and of course, we expect that because of all these reaction some amounts cells synthesis is occur and therefore, cell synthesis reaction we are not able to tell this very easy to represent, I have just represented cell synthesis.

So, we expect that ammonium which is formed in reaction 1, is what is going to be used for protein synthesis to make the cells. So, it is well known that if ammonium produced in a reaction then, that will be use for cell synthesis. This is 1 important result that comes out of experiments in Biology that Nitrogen that is fixed, because of Biological reaction goes to form a cell; that means, whatever ammonium is produced will form cells. So, let as try and look at this data in some detail. So, what you want to say is that, if I say this is reaction 1, this is X1, if I call this as X2, if I call this as X 3, call this as X4, call this as X5.

So, there are 5 reactions that are taking place correct, and how many experimental data do you have, we have experimental data we are able to measure, what are we able to measure we are able to measure ammonium, we are able to measure NO2 minus. So, we have 3 experiment data, there are 3 reactions. So, we should be able to find out what happens, 3 independent reactions, 3 measurement therefore, you should able to tell what happens to Nitrogen. And then, we have we have measuring this as well in the form of C O D; therefore, we know what is happening to Carbon. At least we know what the change that is happening is.

Now, what I am saying is that, if we postulate then what ever ammonium that is fixed in the reaction; see this reaction is called fixation inorganic nitrogen getting converted to organic nitrogen it is called fixation reaction therefore, if this actually happens, then we can say that all this ammonium nitrogen goes into cell synthesis or in other words, what I am saying is that, if X1 is known, then X4 is simply Alpha times X1, this is the

assumption that we make. What is alpha? Alpha is grams of cell, but gram of nitrogen is this clear. If there is nitrogen fixation in the environment that biological nitrogen goes into form cells and the ammonium cell form simply alpha times X1. Where X1 is the biologically produced nitrogen, this is not a bad assumption because, there is a lot of data which suggest that in, if ammonium is produced biologically it is goes to some forms X.

Now, you notice here that we have 3 4 reactions and there are 4 measurement therefore, if indeed and postulate is right, we have a complete description of what is happening and therefore, we should be able to tell, what is the amount of cell mass that is produced. And how, the production cell mass depends upon the process variables. What are your process variables, your process variables are, s you can see from here may your feet rate the rate, at which you feet, or may be the Carbon to Nitrogen that, we provide in the feet or may be the composition at the feed itself. We know, the composition of the fee we know the C by N that we have chosen therefore, in principle if postulate is right; you must be able to tell, how much cells are formed and therefore, we should able to predict how the process is running. Now, context is let us we trying to clean water.

So, this is there Now, the obvious example that all of us might be interested in. What are we interested in, we are trying to get rid of the pollution in water. And that pollution is measured in tempt of C O D in terms of, Nitrogen in terms of Nitrate. So, it is a complete description what is the quality of water that is start with and what is the quality of water you end up with therefore, we must able to tell how to clean this water to the extent that you desire.

So, since what you are trying to say is that, this formulation that, we have provides a way of telling, how to design equipments to be able to produce what we want. If that production is clearly specified we must be able to tell from this model, if it is correct; what will happen to 3 processes, and what we can do to design such processes. So, this is the exercise that we want to do. Now, let us just look at this data and I will ask you few questions; you have 1 2 3 4 5 6 7 set's of data out of 7 large number that I have given you. Let us look at, what happens to Ammonium, what happens to Nitride just look at the data. You studied with 90 20 15.4 this start with 90 goes to 15.4 is start with 107, becomes almost 0; that means, in this process Nitrite is almost fully consumed and you can see amount of nitride is not very large.

Now, how much Nitrogen we putting in, how much Nitrogen is in the output is starting with how much Nitrogen 107 plus 90 about 197. And then, what is we end of with how much 15.4 and almost 01.1 about 16. So, we put in 197 units of nitrogen and what we get out is only 16. So, huge amount of nitrogen is lost correct. So, I want to you to appreciate this in agriculture huge amount of nitrogen is lost; I mean, intact huge amount of data which says that 85 percent of nitrogen is lost. Now, this tells you clearly you know it is lost you want to know why, do not know. Now, you look at carbon measured as C O D 385 become 90. So, you can see Carbon is lost Nitrogen is also lost.

Now, whether this nitrogen which is lost, is it fixed as cells or is it going up into the atmosphere we do not know. As for this model that, we have written the model, we have written you are only accounted for nitrogen that is going in to the atmosphere, we accounted for the oxides of nitrogen NO2 minus and NO3 minus. So, postulate is a nothing else happen; suppose N2O is formed, we do not know, that was. So, go out you see. So, we do not know, whether it is N2 or N2O; we are in some doubt, but what is important is that, the huge amount of nitrogen lost in the experiment also we find huge amount of nitrogen is lost.

Now, if you look at it is quickly see the correlation, how much ammonium is lost, how much nitride is lost. Do quick calculations see that ratio do a mental calculation do a mental calculation, this is 75 and this is 107 to 75,107 divided by 75 is what 01.3, 01.4; look at the next data 51 and then 06.3, which is about 45 and this is about 60, 45 to 60 that ratio would be 60 is your 45 about, 01.3, 01.35; please look at it is important to recognize that, this data suggest this ratio, the loss of ammonium to loss of look at that ratio. See, soil huge number of reaction occur in soil we all understand that we have modeling it in terms of simply 4 reactions not thousands of reactions and look at the kind of order that you can see in the data.

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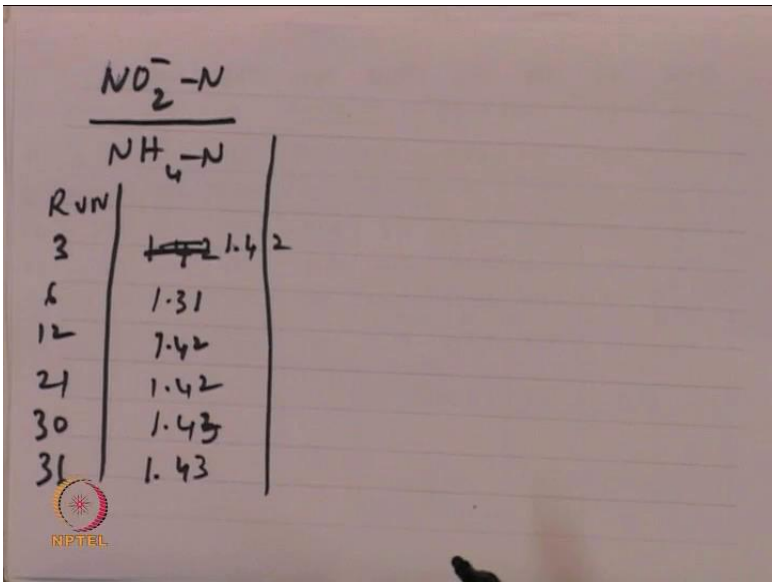

So, if you look at each of the data and tell me what is this ratio please quickly, what is the ratio of loss of ammonium to loss of nitrogen loss of nitride to loss of ammonium or calculate this ratio loss of just calculate loss NO2 minus divided by NH4 plus, roughly tell me some numbers what is that ratio find that ratio. Quickly please, let me write here, see this is what we want to find out NO2 minus divided by NH4 plus. please tell me these ratio, run number i will just writing down 3 6 12 21 30 and 36; please tell me there is a ratio, have you all got this data, you taking down this data, give me just number please; no, I want the ratio no 2 minus 1.3 1.4; whatever that number, 1.4 across reasonably constant number 3 1.4 2 and then run number 12, 1.4 2 run number 21, 1 4.2 run number 3, 1. 43 and run number 36; what I want to draw your attention, even though many reaction might be taking place when we look upon this equipment in terms of this ratio NO2 minus 10h for plus, it seems to suggest ratio is reasonably constant.

What meaning can you attach to an experiment in which ratio remains reasonably constant, how do we understand, what can be say might be happening. Look at these reaction, NH4 plus NO2 minus giving you N2. What do we expect if this reaction is taking place, what do we expect, it should be 1 to 1 the ratio should be 1 is to 1 it is not 1 is to 1. This is the reaction that is responsible for loss, this would not be able to explain the difference it mean, NO2 minus and NH4 plus correct something more is happening let us see how to understand this, reaction 1 and reaction 2 that could explain this. So, said again.

We do not the from the data it appears that there is not much note 2 n o 3 minus that is true. So, this reaction may not be as important, but what extent is reaction 1 we do not know, whether it explains all that. So, what we have to now do, use to be able to model this tell how much in the data, how much is X1, how much is X2, how much is X3, how much is X4 correct. This is clear, from the data is a multiple reaction you know how to handle multiple reaction. So, given this data what is X1, what is X2, what is X3, what is X4; can we find out, that is what we should do, how to do that. So, let me write it here you please remember this reaction; I am going to write, I will write this, let me I will write balance for NO2 minus.

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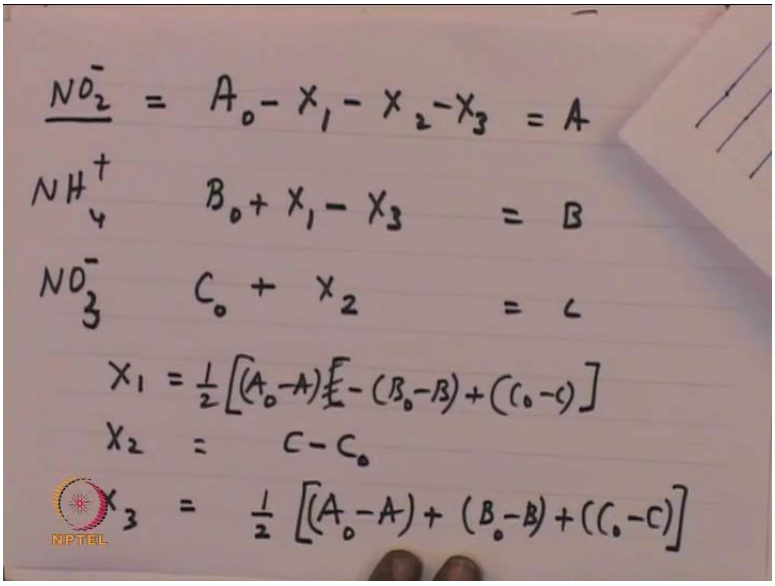

NO2 minus how much, what is equal to what how much is coming in let us say, this is a not is coming in and it is reaction. NO 2 minus is consumed in reaction 1, reaction 2 and reaction 3. So, say it is a not minus of X1 minus of X2 minus of X3; X1, X2 and X3 are the units of let us say, milligrams per liter or some appropriate units is it alright. And the NH4 plus notice here, NH4 plus is in reaction 1 it is form, in reaction there is consumed.

So, it is B not plus X1 minus of X3 is it alright, NO3 minus C not and it is, what happens to N plus X2. So, I call this as equal to A, equal to B, equal to C; A, B and C are measured quantities. Now, can you tell me what X1 is, what X2 is and what is X3. I will write the answers, please tell me, whether it is this is equal to C minus C not is it; X3 can

we just solve this equation and tell me, I will write answer here, but you please tell me whether this is, I am just writing the answer.

So, you have to tell me whether it is, you solve that equation and tell me whether this is. So, can we now say, now that the data see the data is given? Can we now find out, what is X1, X2 and X3 is this clear, what is X1, what is X2, what is X3. I want to tabulate that, you have this equation with you all of this what is X1, what is X2, what is X3.

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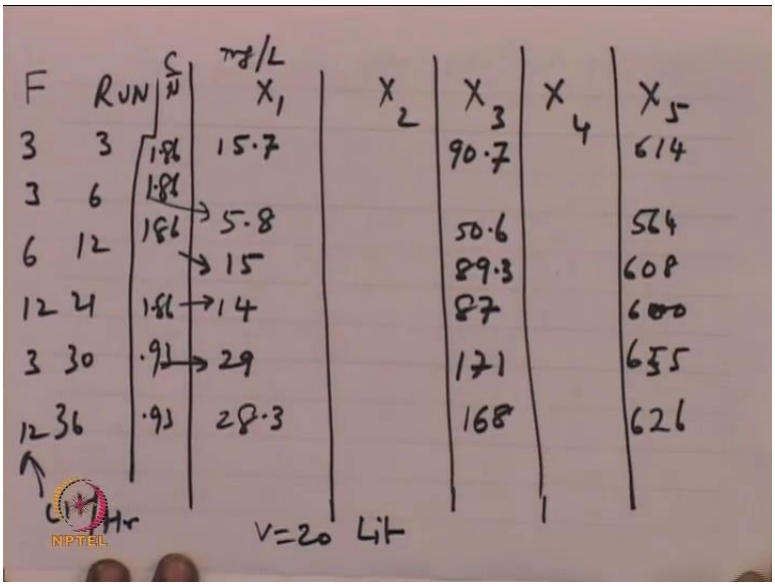

So, I want to make a table of the answers for these 6 data. So, this is run number 3 6 12 21 30 and 36; X1, X2, X3; I want to write X4, I want to write X5 also I want to get all the numbers from you. Run 3 6 12 21 and 36, X2 you can read out, X3 you have to calculate, but anyway you please tell me the answers, I want the answers, which we can go 1 by 1 run 3 what is X1. Let us do 1 by 1 please help run 3 what is X1. So, that all of you get the answers right X1 for run 3 place, 15.7 it is in mile grams per liter, run 3 is 15 and X3, 90 .7. Similarly, for run 6, do X1 for run 6. So, run 3 this is what the answer, I have been given you all agree tell me for run 6 place, 7.5 and 46 that is what I have got. Anybody else run 6 here.

How much?

Student: 50.6 and X1 5. 8.

5 point 8 is it not?

Anybody why I am not got a slightly different answer and 6.7 in 6 59 40 it means, we calculate this is correct 5. 8; everybody gets it and 50.6 is correct, in that, I have made a mistake is it run 12 what is the answer? X1 15. And X3 89 point very good run 21 14 and X3 87 then, comes run 30 run is how much, run 30, 204 is about 140, 204 plus 140 is 340, 170. Actually 130 X1 29 that is what I am getting and then, X3 I am getting that also run 36 everybody is done, X1, X3, X2, X3 tell me run 36 run 36 please, 28.5. And the other 1, I got 168; anyway this is, I hope all of you have the data. So, I can put this on top.

So, this how the experiment look X1 and X3 what is the ratio, X1 to X3, X3 to X1 around 6 why this 10, if you plot all these 54 sets of data, you will find the actually it is reasonably co-relation around 06.6 around 6.6 is what I expect based on the data. So, what we are saying is, that X3 to X1, see this reaction taking place in this soil environment, as for as the model. The ratio of X3 to X1 seems to be reasonably constant

Now, how do we explain this, what does it mean, what meaning can be attached these are the reaction that we have off course, what happens is you know 100's of reaction may be happening, but we are that only these 5 reactions are sufficient to understand what is going on. We find that, X3 to X1 is about 6.6; I like the number 7, there are 7 electrons in the outer most cell of nitrogen. So, therefore, I like that number 7, the ratio is 7 this is what, I like. You know, does not mean, that I am right.

So, like to think that it is it is 7 1 by 7 is 0.14 for last 50 year, the data on agriculture says that 8 5 percent of nitrogen is lost. What is X3, X3 is nitrogen lost and what we are getting, 5 percent of nitrogen is lost on other words very simple experiment which is nothing to do with agriculture you know and these experiments, have done with equipment very ordinary kind of equipment you know and all that get nothing very sophisticated, but it is able to give you insights into reaction, which are extremely complicated that see too many things happen.

On other words, if you have the right model you can handle an extremely complex reaction that is the message of the experiment like this. What we are saying is that, X1 what is X1, X1 as per this reaction is the nitrogen that is fixed, NO_2 minus going to NH_4 plus, which means that biologically the nitrogen get's fixed that is why this. So, what is being said is this ammonium, would get fixed in the cells so; that means, if I tell you

alpha, the grams of per gram of nitrogen. Suppose let us say, if you look at bacteria typical soil bacteria about 12 alfer is about 12. If you look at groundnut alfer would be around 20, if you look at wheat alfer would be 60. if you look at sugarcane alfer would be 300, if you look at wood alfer would be 200 know, these are all well know numbers. How much nitrogen is there in the cell, is a well documented kind of information you can get it from the literature.

So, if you know X1 is to be able to tell how much cells are produced and therefore, if you are doing a waste treatment for example, you know how much cells are formed and therefore, how much sledge this produced waste treatment sledges is a nuisance people do not want sledge. So, you can tell from here how much sledge will be produced in your process, once you made this measurement you can tell you would handle. So, much sledge. So, much of cell max how to be handled; now, in this 6 sets of data that I had given you, I have chosen these sets. So, that the X1's are always positive, there are many sets of data where X1 is negative.

What is X1 negative mean goes the reverse way and therefore, no cells are produced and therefore, no sledge is formed therefore, you do not have to deal with problem of sledge in waste treatment. You understand see insides that, can give you is enormous. So, by appropriately choosing your process, you can produce cells or you may not produce cells or another word cells are essentially expiring. You know there are cells in the system which expire they do not grow, they grow, but they do not reproduce is this clear what we are saying. Now, X1, X2, X3, X4, X5 are in the units of milligrams per liter clearly, if you want to look at reaction equipment this milligrams per liter does not make sense thus it where is a data see you can look at this data here the flow is very different.

So, actual production will be what will be whatever X is you have calculated multiplied by the flow divided reactor volume correct. So, if you want to express what is happening in your process you have to multiply this by f divided by volume of equipment then only you can tell that is the productivity per unit volume per unit t1 is this clear. So, we should multiply the X's by F divide by reactor volume which is 20 which is given V is 20, V is 20 liters it is given. So, you can express all the numbers. So, that you know when your operating at 12, the productivities will be F multiplied by this and all that. So, you can calculate and find out the productivity clear. So, be careful understand that you know productivity is a very different, because the flow rates are very different.

Now, what is X5, quickly tell me you can read out from your table X5, where is the X5 this difference. I just want to write down those differences, tell me the numbers please; run 3 what is cod loss, how much? Run 3 6 6 1 4 second one 564, 3rd 608, 4th 600, 5th 655 and 630, 626 these are the numbers. So, if you multiplied by F, F is not mentioned here, F is I will put F here. So, it is 3, 3, 6, 12, 3, 12 these are flow rate in liters per hour, these are the flow rates in liters per hour.

So, we can calculate productivity now, looking at X5 and X3. So, first this is C by n is 1 point, I have put this C by n here, C by N this is 1.86, 1.86, 1.86, 1.86, 0.93, 0.93. Now, generally biological processes have a very strong dependence once C by n. So, you find out what is this ratio C by n is 1 by 8 6; this ratio in you have to find this ratio F multiplied by you know, productivity wise otherwise you cannot compare. Please find out these number, which is F multiplied by X5 divide by volume that is how you have to calculate. When you do that, there is some calculations involved, but do not worry about that. What you will see, some of you done this already, what you see is something interesting we will not do this now, I will just tell you the result you can do it at home.

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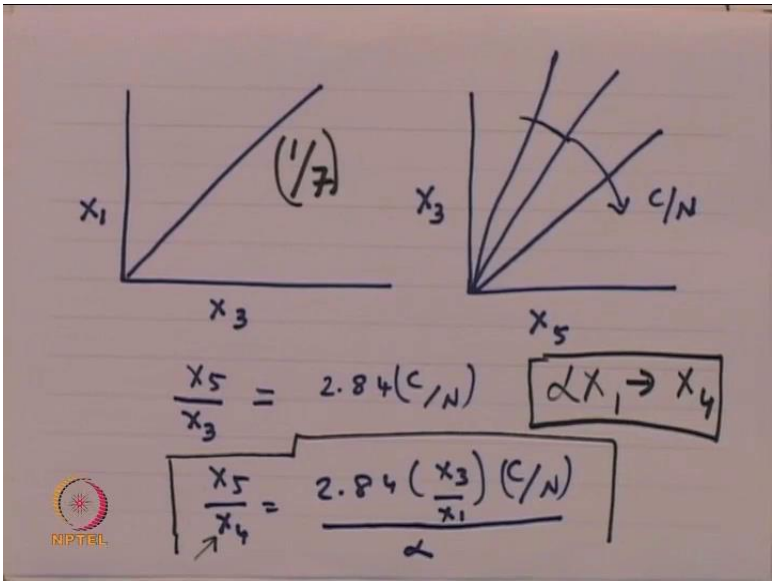

If you make a plot of let us say X5 the units are say milligrams per liter per hour say, X3 also in the same units of milligrams per liter per hour. If you make this plots, you will find there are straight lines and it will be like this, C by N changes some of you done, I understand many of you may not done this what it says is the loss of nitrogen this the

loss of nitrogen per unit volume per unit time, this a loss of Carbon measured in cod per unit volume per unit time all biological processes, you had this kind of relationship that loss of nitrogen, loss of Carbon are co-related in soil they seem to be highly co-related as we find. In these kind of data and what I had asked to do is to find out that kind of co relation.

So, that we can use it for various purposes including design. I have done that, I will show you those numbers see I have done this your answers look something like this. That means, when you make plot of loss of nitrogen, to carbon measured as C O D I find, I was very surprised to see such good straight lines. But they seem to you extremely good lines showing the co-relation extremely high and then loss of, I mean production of nitrogen to loss of nitrogen, that ratio appears u 1 by 6 1 by 7 I like to say it is 1 by 7 it is not 1 by 6.6 so, it is 1 by 7. So, that you get a co-relation like this, see this co-relation is important, what does it say, it says in biological process.

So, this comes out of curve fitting you would have to do this in your at your home, when you do this fitting I get something like. This loss of carbon measured as C O D X5 and then, I will do first loss of carbon divide by loss of nitrogen, this ratio 2.84 times C by n, this what comes out of the data. Now, if you assume that whatever X1 is form, it goes to form cells therefore, alpha time X1 is X4; if you make this assumption, then the cell produced 2 carbon. Lost is look something like this; that means, loss of carbon measured in C O D to production of cells on the right hand side is the ratio X1, which I say 7 C by n, is of the reaction environment. There is something that we will choose, alpha is the produce productive of produce if it is cell alpha may be 12, if it is groundnut alpha may be 1620, if it is wood it may be 200 whatever.

So, we want to test this particular equation whether it explains what happens around the world. Let us do a small test, how it predicts what happens around the world, see 1 data that we know is that in the U S; lot of data is there, in the U S. This carbon to nitrogen in soil is about seems 20 or something like that, some says 15, some say 20. Let us take it as 20 for alpha is 75. So, what is the right hand side, 2.84, it is 7 close to 20 this 20, 400 alpha is 75; 400 divided by 75 is how much, 5.3 correct; 5.3 now, 5.3. So, left hand side also we should get 5 point see; that means, this cell production what is the X5, what is the carbon lost from soil now, there is lot of data, which is around available around the world, where about 20 tons per hectare per year is the kind of carbon loss from soils.

So, X5 is about 20. So, what is X4 around 4. So, if you look at the U S you will find that, the production of con will be around 4 tons per hectare, if it is an unfertilized soil, but moment you put fertilizer it improves. So, for unfertilized soils in the U S will have a product con production about 4 tons per hectare, plenty of data is there moment you put nitrogen what will happen C by n it will come down. So, once C by n comes down your X4, will increase. In other words, what we are trying to say here is X5 represents energy and that energy you can harvest and get it in the form of food by appropriately adjusting C by n. So, what is being said is, soil has energy in the form of X5 which is soil organic carbon soil has carbon.

Now, you have to harvest that, in the form of food, if you do not do anything the natural C by n will give you let us say 4 tons per hectare. Now, if you put external nitrogen in the form of urea reduce the C by n appropriately this the production will increase. So, what is this C by n given you, it is only insured that, you are able to harvest more of the soil carbon as food is that clear, we are harvesting more of carbon in soil as food this is what this hole equation is saying. So, by adjusting the carbon to nitrogen ratio soil, you are essentially ensuring that more carbon of soil can be return to you as food. If you look at India for example, C by n in India is quite high the reason is that the respiration rates are very high in India and things like that.

So, C by n about 30, 35 is not uncommon suppose you say let us say we are trying to grow corn in India instead of 20 C by n is 35. So, what will be our production, X5 is see the X5 is still people take it as 20, but the case in India is not the case is not as highest 20. So, assume it as 20, what is X 4; if it C by n is 35, 2.15. So, what we are saying, if there is enough carbon in soil you can still get a production of 2 tons per hector of con, but what seems to happen is that, carbon in soil is also very low particularly in our regions because of respiration. So, carbon is very low in soil means, what there is not enough carbon in soil to be return as food. So, even if you put fertilizer you cannot get much food out of soil because there is enough carbon in soil.

So, what is being said is that if you are trying to grow you have provide glucose then only baker's yeast will grow, if you do not provide glucose carbon source is not there means it cannot produce in the same way if you want to grow food you need carbon in soil, simple putting fertilizer in soil not going to give food. This is the point, I am trying to put across you whether it is growing baker's yeast or making alcohol in fertilize in a

formatter or growing food the fundamentals are not very different. Essentially it is trying to harvest the energy of carbon which has to return to you, that is what we are saying.

So, this equation essentially tells you that, if you have carbon in the environment you can harvest it provided you are C by n is appropriate. Now, you can explain why you can produce 600 tons of tomato in because alpha tomato is what 98 percent water and the alpha value is something like 600 or. So, there is practically no nitrogen. So, when you producing the crop is does not have much nitrogen, your production will be very high it is nothing to be supersized about, somebody comes and says I will produce some. So, many 100 ton 400 tons of tomato per hector it is to be understood moment, you understand this you know you can understand it is possible it is not that it is not that.

So, these are the important issues that you must recognize that, in whether it is producing alcohol in a formatter producing, baker's yeast in a formatter, producing penicillin in a formatter or producing in soil fundamentals are no that you need a carbon source. You need a nitrogen source and an appropriate environment for your organism to work, this all it says, see the example I took carbon C by n of Indian soils are quite high, the reason it is high there are number of reasons for this returning organic to soil is has somehow be discontinued for some reason after syntactic fertilizer have come. See that; that means waste organics which is previously going back to soil very effectively, because it is the form environment even in a village, but now a days this all urbanized and therefore, the waste is accumulating in the urban area it is not returning to the form.

So, C by n is very high and therefore, you are productivity is very low X4 is very low, 2nd reason is that since respiration are very high in our environment, the carbon in soil is itself quite low. If you go to the U S the carbon is very high, because is a temperate environment to the carbon is extremely large and that is not the case in our environment. So, this is two difficult situations which we have to handle, part of the reason why our productions are not as high C by n of a natural environment if you go to a forest C by n is fixed, because it is evolved or millions of years.

So, C by n of soil would not have change; see if you go to north east source of north east. slash and burned and in the core see they slash the forest they grow for a number of years and then they abundant. The reason is that forest comes with good high good value C by n around 14 into 15 C by n is. So, you give very good crop yields a very high you know

and after 4, 5 years in it collapses and then you leave it let the comeback after may be 10 12 years that is what the tribal's are done in the north east and by and large this practice has kept the forest in reasonably good shape is not that the forest have disappeared there are pretty good shape. On other words C by n seems to be an important parameter for productivity of biology.

So, this is in our hand C by n is in our hand, but what is important to recognize that when you decrease C by n you are harvesting the carbon of soil.

So, higher the C by lower the C by n high is the rated which you are harvesting, if what you harvest if you do not return your waste that soil is going to deplete rapidly. See we are producing by agriculture we are producing more, but our waste are not returning to soil it is going in to ganga Yamuna, whatever it is not going back to form and that is the problem which is responsible for lower productivity. X5 is low C by n is high both seem to be working against us is this clear. This is point is the most important point as per as biology is concerned that, the there is an inverse relates alpha is high means you will get very high production you will get huge amount of tomato understand.

The nitrogen is low see what happens is that, people would like to calculate what is the energy that is required to do whatever you are doing, whether it is producing penicillin it producing baker's yeast or alcohol or producing in soil whatever is the biological environment how much energy is required to do what you want. Now, we have said that these 5 reactions is what is taking place correct reaction 1 2 3 4 5. So, there is an energy delta H delta free energy of formation free energy for change for each of these reaction similarly I mean standard heats of formations and all that. So, that you can calculate what the delta H for all these reactions is, what is the energy there is required for these reaction how much energy is released by this reactions. So, if you assume in soil there is no loss of energy in the sense that this completely you know synergized fully synergized. So, all the energy fully utilized.

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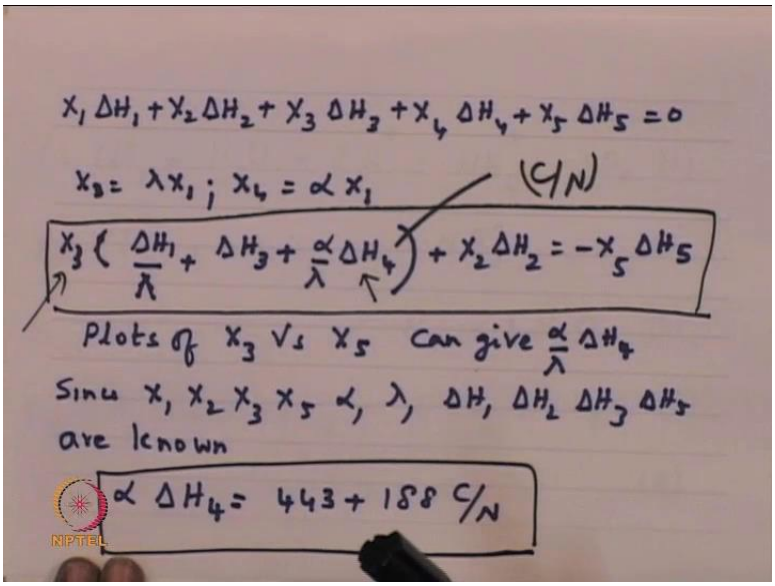

Suppose we assume which means I say that, this applies I say that, this equality applies which means X1 delta H1, X2 delta H2, X3 delta H3 equals to 0, this an assumption we do not know whether these are right or wrong. Now, we are saying that the X3 and X1 are related by this X3 to X1 we are saying is 6.6; I am saying it is 7 we can quarrel, but let us say it is lambda. So, X3 to X1 based on our experiments saying it is lambda correct and then, I am saying that, you know whatever's ammonia produced biology it is fixed in cell therefore, X4 that are cells is produced simple whatever is X1 this produced multiplied by alpha is known. If it bacteria of soil is 12 if it is whatever plenty of data is there.

So, on other words this sigma Xi delta H i equal to 0 then it give you this kind of relationship, this relationship which is look carefully it is an interesting relationship, X3 is know. And inside here the only unknown is delta H4. What is the energy required to make the cell; these all these are well in in principle we can plot X3 verses X5 correct, X3 verses X5 we can plot get data is there X3 data you have X5 data you have yes or no; therefore, if you turns out that, it is a good straight line if it turns out and it is often the case because this term is not very large this term is not very large therefore, it terms out to be good straight line you are data will tell you is a reasonable good straight line you will get.

So, that from the slope you can find out what is the value for delta H4 is that clear? What

I am saying. So, these see we have done these experiments for each C you can do this for every C by n, this can be done for every C by n. So, what are we saying, we saying that we conduct experiments at different C by n and find out what is the energy that is required for growing this for making this cell? This cell can be paddy wheat wood tomato, whatever baker's yeast which whatever is your organic of interest. What is this delta H4, it is a energy that is required to grow that cell, I mean cell synthesis how much energy is required for cell synthesis.

Now, then once you have the data you can plot the data and then, infect there is excise that I have asked you all to do, I do not have a good answer, the answer I like to give is that, life is reward over millions and billions of years clearly it would have made good use of energy therefore, energy is in short supply always therefore, it make the best use of whatever energy it has. This an assumption it may not be right it you know, but it appears from, whatever number that emerges from very simple lab experiment that it is not wrong. What we are saying is not wrong, this saying that appears to be the great effort to maximize or utilize energy available most efficiently I am not allowed to dissipated. This is the kind of answer that, is coming out of the data you should look at data carefully. What we are saying now little bit more, that the energy that is required to make the cell depends on C by n and that is the kind of relationship that emerges from the fitting.

So, when you fit the data the energy for cell synthesis can use per gram multiplied by alpha equal to this. So, suppose you are growing a crop, which is alpha is 200 then clearly the energy of cell synthesis low. If you are growing a crop where the alpha is 10 the energy of cell synthesis high; there is 1 result, second result is that C by n, higher the C by n higher is, the energy that is required to grow the cell. In other words it is say, exactly what farmers will tell you that, if there is not in a if your C by n is high in soil as it is in India, the energy required to grow crops are very large. Same crop you grow in the U S the energy require is much lower, because C by n is much low.

On other words the U S environment gives you a for more C by n the forest environment of northeast gives you a for more C by n for you to have much higher productivity. On other words, if we can maintain forest everywhere we have the highest productivity, if we can a food leave on forest by large the productivity is extremely large, that is the kind of message that comes out of ecology.

So, what I tried to do is that project what we call as ecology natural process and all that, in terms of numbers thermodynamically we can understand. That energy is most efficiently used in in a very whole sum forest environment, in agricultural environment energy is not use so, efficiently and therefore, the energy consumptions are much larger. For example, in typical agricultural land in the world would have production of about 6 tons per hector, if it is a forest it will be 22 tons per hector, but forest will produce wood where the nitrogen is only 0.5 percent, while agricultures will produce food for the nitrogen may be about 2 and half percent.

So seen in that, terms you cannot say it has inefficient because energy wise it may be just as good quantity wise it may be different. So, we have to do look at all this things not only in terms of quantity, but in terms of energy as well. So, what I try to do here is a to project both quantitive numbers and energy numbers. So, that you can see how the natural of system perform so, that is the excise problem sheet, whatever the number is. So, there is enough that you can now, finish of it. I will stop there.