Downstream Processing
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Lecture - 23
Membranes (Continued)

For the past few classes we have been talking about Membranes, how to separate, dissolved, salts, ions, biomolecules using different types of membrane. And we will continue in this class on further on membranes. If you look at the membranes you have membranes process like micro filtration, ultra filtration, nano filtration and reverse osmosis, dialysis, electro dialysis, and so on actually. Each one has different types of membranes we have hydrophilic membranes, we have hydrophobic membranes it is used for separating practically large number of varied components.

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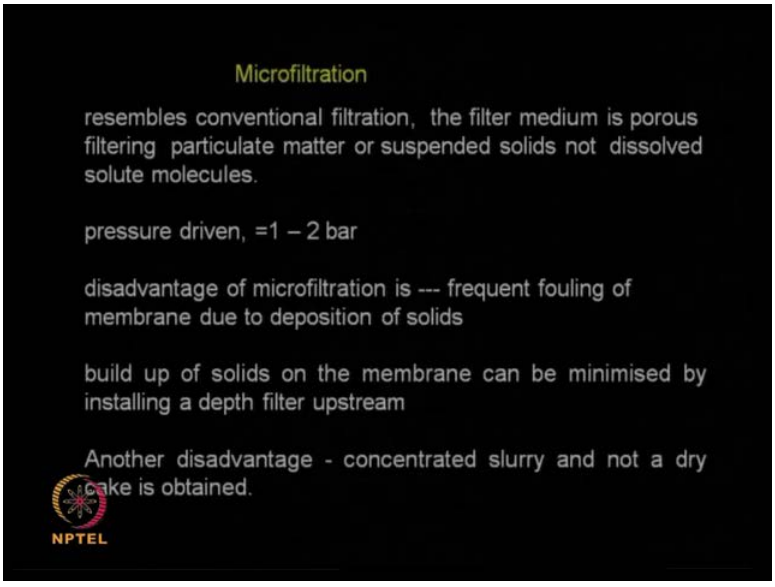

We did talk about micro filtration some time back, let me again recap on that, it resembles like a conventional filtration. So, there are small porous in the membrane material, so these solids which are very small then the porous will go through and remaining solids will get filtered out, so it is almost like a normal filtration process. So, because there are porous the pressure required is also much less, you use 1 to 2 bar, almost like the normal filtration where we also use 2 or 3 or 5 bar pressure. We do not go

very high in pressure, but the disadvantages micro filtration are just like your normal filtration it is going to be deposition of solids, frequent fouling of membrane.

Fouling I did mention about fouling last time, fouling could be bacterial or biological in nature or it could be because of the polarization, next concentration polarization effects and so on actually. So, and micro filtrations do come across these problem both the fouling as well as the deposition of solids, so build up of solids on the membrane. How do you minimize it? We can have here depth filters upstream or a normal conventional filter upstream.

So, it will capture all bigger particles and then you go to the micro filtration, and then you resort to further filtration. Another disadvantage of micro filtration because the pressures are not very high where you are going to get a concentrated slurry you will not get dry solids after filtration. Ideally you would like to have a dry cake after filtration because the storage or disposal becomes easy whereas, which a slurry it may contain about 10 15 20 percent water, so then it is not very nice idea to store it.

Where, will you store because of 20 percent water, so membrane will lead you into slurry system and you can apply very high pressures because membrane will mechanically get damaged. So, that is the disadvantage of that, so what do we do once you do this type of membrane filtration, and you want geted of the concentrated slurry, sometimes company is will resort to solar drain.

That means, they will have open space and may be they will have a long plastic surfaces on which this slurry is put in, and water will get dried because of the heating. And the solids which you get you collect it and use it for either further processing or disposal or land fill or annual feed whatever you think off. So, the you need to resort to this type of the solar heating.

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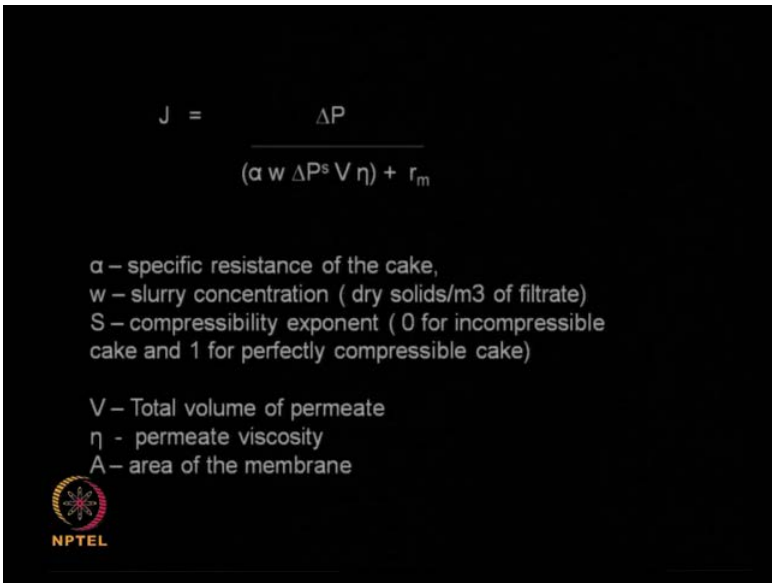

The equation this is standard equation for the flux, you have the driving force because of the delta P, that is the pressure and then if it is a compressible material. If you remember the very, very early class, now where we talked about compressible solids and incompressible solids, we have equation like this delta P raise to the power S and S we called it as a compressible exponent. So, it is 0 for incompressible, so when you substitute 0 in the incompressible delta P raise to the power 0 becomes 1.

So, compressibility will have no effect on the flux whereas, in the cake is compressible, then you put S as 1, then your driving force gets decreased because if the cake is compressible. What will happen? If you put too much driving force or too much pressure cake will get compressed and the flow rate gets decreased. So, we need to sort of balance between that, so that is why will have a term delta P raise to the power S in the denominator.

In addition we have terms like V that is the total volume, which you want to filter eta is the viscosity, w is the slurry concentration, alpha is the specific cake resistance. So, this I hope you remember the Darcy's equation many, many, many classes back we studied and plus see you also have rm resistance offered by the membrane itself. Unlike a filter cloth membranes may offer resistance to flow because the pore sizes of very, very small that is why.

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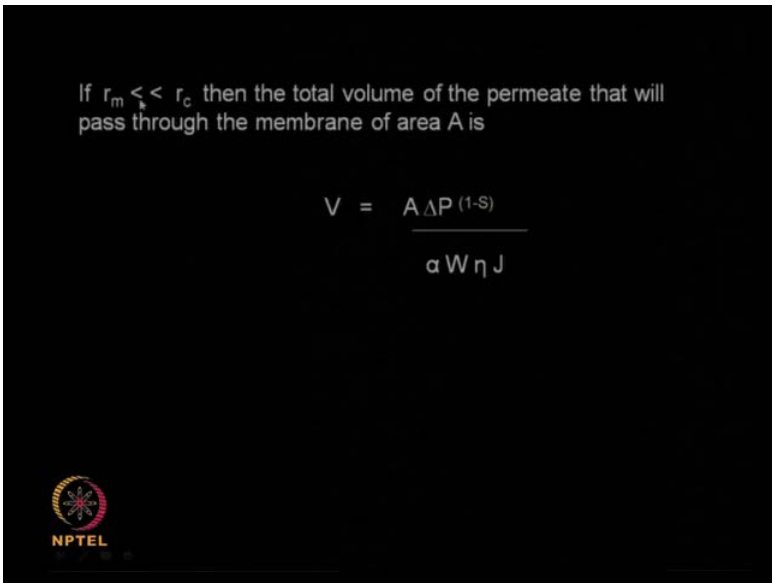

Now, if resistance offered by the membrane material is very small and then you get a very simple equation, that will give you the volume that is getting permitted or that will pass through the membrane area given by this formula. So, these again like our old filter relation equation, this is the governing equation which determines the permeate flow.

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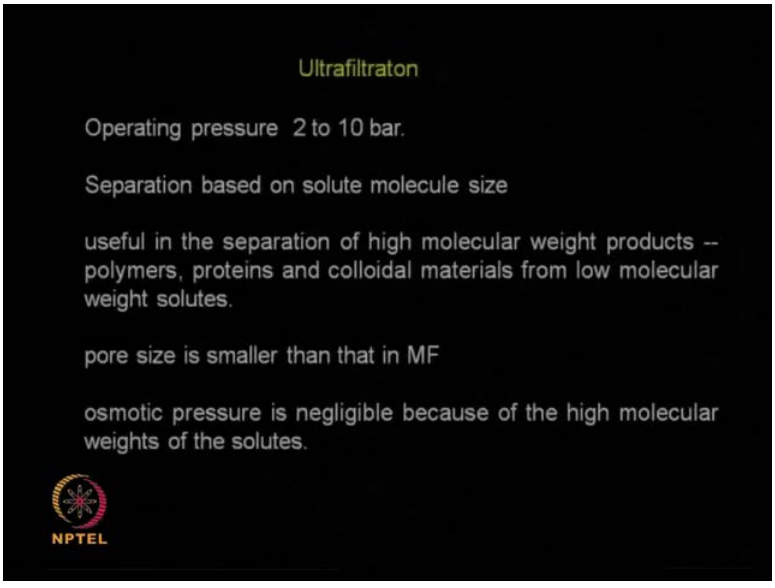

Now, ultra filtration of course, the pore sizes are very, very small and operating pressure is also very high when compare to your the micro which 2 to 10 bar. So, this is the

separation based on the molecular size, so we can use it for separating high molecular weight products into smaller molecular weight products.

So, we can use it for separating polymers proteins colloids from salts now ionic salts. So, here the pore sizes much smaller than the micro filtration, much, much smaller, that is why we are resorting to higher pressure. So, when the pore size is very small you have to go for higher pressure here, osmotic pressure is also negligible because higher molecular weight of solutes that is what we are dealing with actually.

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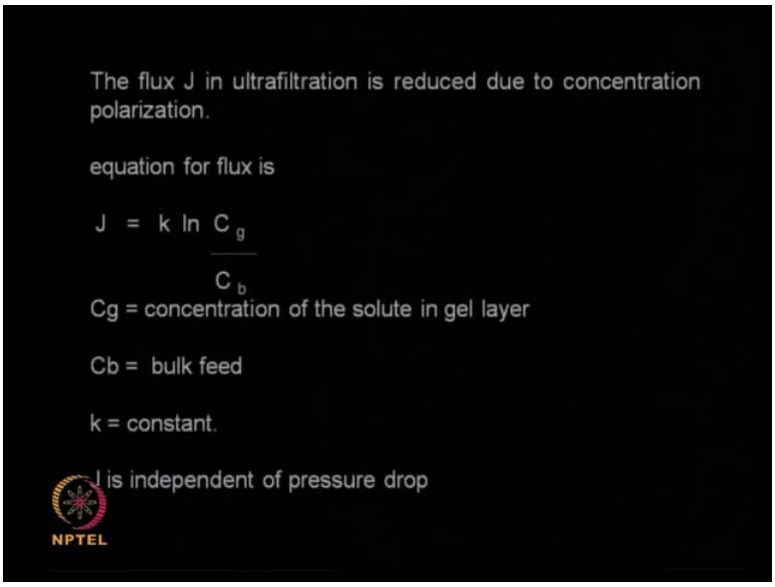

Now, in ultra filtration the flux is based on the concentration polarization, so there is going to be a concentration of the solute build up on the upstream side, so because of that the flow of the solute is getting disturbed. And if you remember few couple of classes back I talked about the concentration polarization and in an equation for the flux, which is given by J.

The flux is equal to k logger than C g by C b, Cg is the concentration the solute in the closer to the upstream of the membrane surface or the gel layer, C b is your bulk. So, C g will be much higher than C b because of the buildup of solid near the upstream surface of the membrane understand. So, k is here constant and now here you see J is independent of the pressure drop, so the pressure does not come into the picture in ultra-filtration whereas, in the micro filtration pressure plays a important role, it is almost like a normal filtration see the difference.

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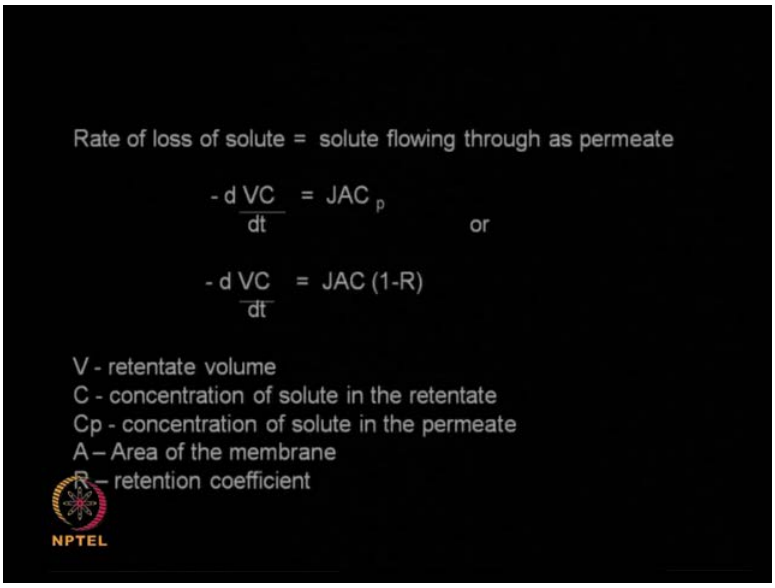

Now, there is going to be rate of loss of solute, because solute will always try to escape, now that will be equal to solute flowing through as permeate. So, the rate of loss of solute will be d by d t V into C, V is your volume and C is your concentration obvious right. So, we have a negative term because there is going to be decrease anything decrease is that, now this is equal to solute flow is J is your flux into area into C p that is concentration of solute in the permeate, so this is also obvious understand.

So, here you have rate of loss of solute is equal to solute flowing through the system as a permeate, now this you write it as the C p you write as C into one minus R. C is the concentration of the solute in the retentate that is the concentration that is remaining and r is here retention coefficient. So, the retention coefficient is 0, then C and C p will be the same whereas, in the retention coefficient is 1, so this will get canceled out. So, rate of loss of solute on the left hand side solute flowing through as permeate on the right hand side.

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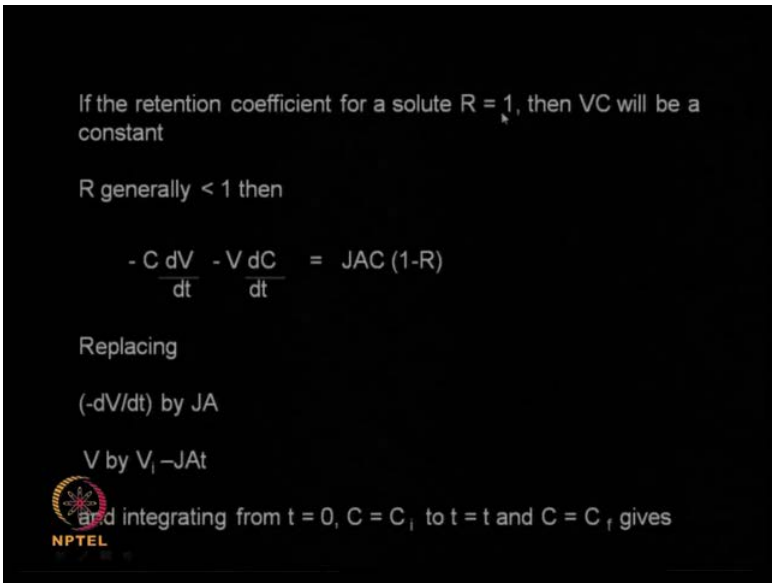

In the retention coefficient for a solute R is equal to 1, then VC will be a constant understand.

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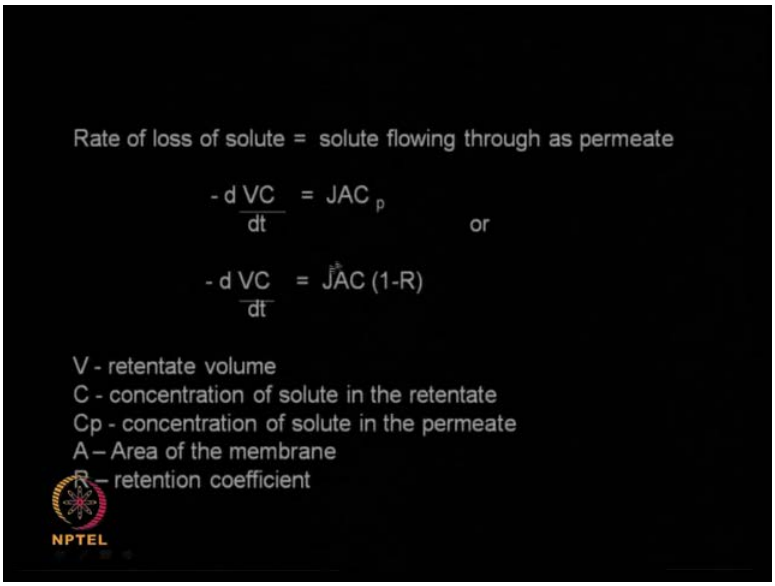

So, if R is equal to 1, this whole term becomes 0, so d VC by d t equal to 0. So, VC is a constant, so a constant volume of solute will get lost over a whatever time you are talking about.

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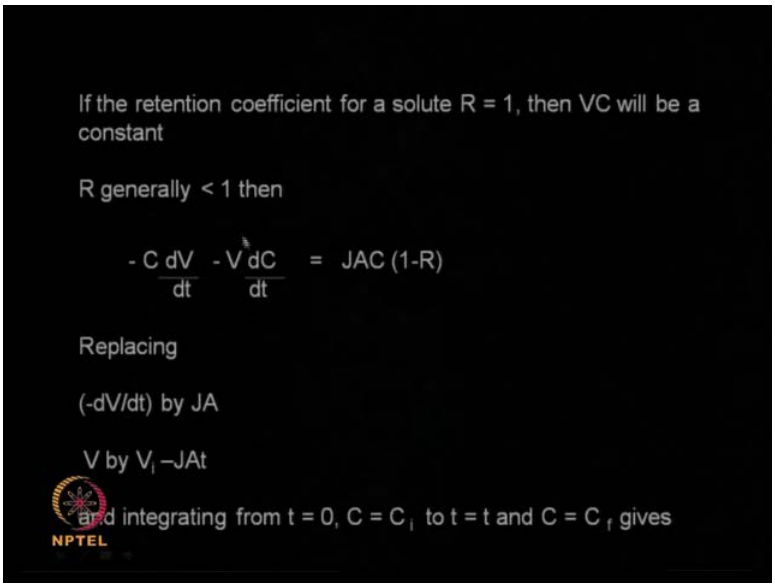

But, R is generally 1 less than 1, so when R is less than 1.

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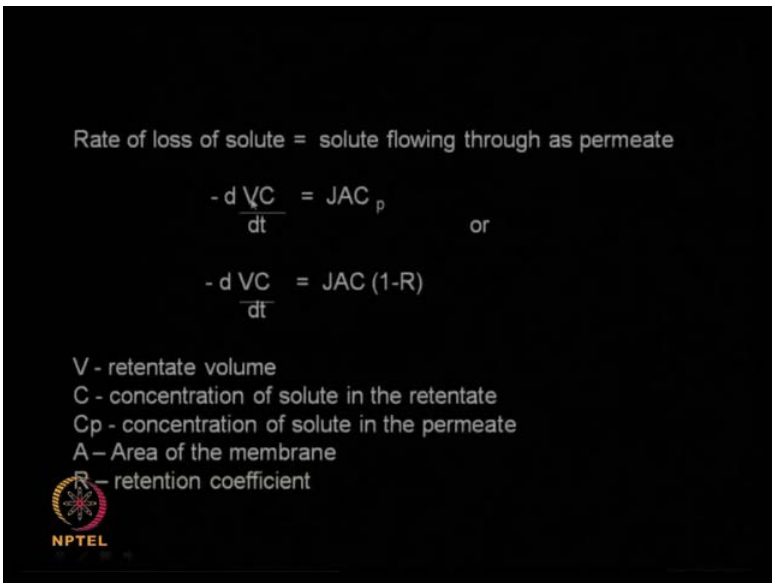

Now, on the left hand side we can differentiate both this separate separately.

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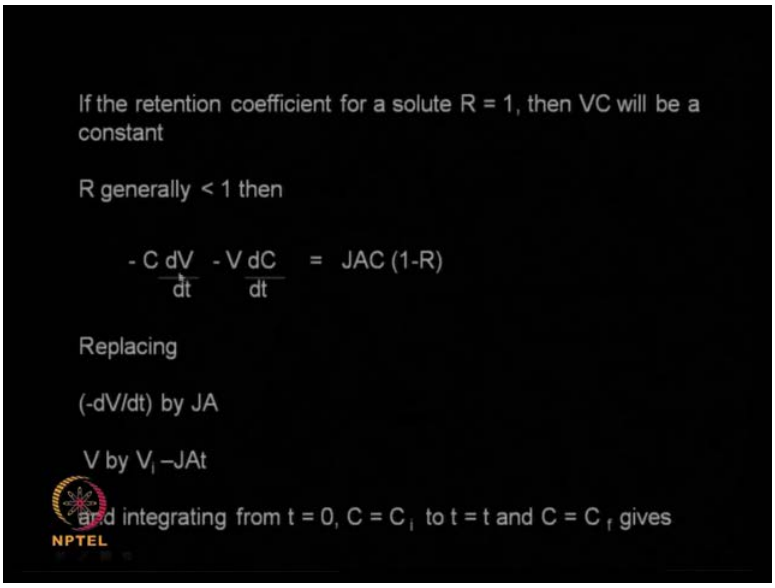

So, will have minus C into d V by d t minus V d C by d t which is equal to JAC into 1 minus R. Now, d V by d t will be J into A that is the J is here, flux A is here area. So, when flux by area is the where rate of flow of liquid correct. That is why, so we can replace by this by JA and now V the volume will slowly keep decreasing because of the concentration polarization agreed.

So, V i could be a initial volume minus J is here flux into area that is rate into time. So, where it we are considering something like a linear decrease the assumption here is a linear decrease in the amount that is flowing through, so V by V i minus J A t. Then we can integrate the whole system at t equal to 0 and C is equal to C i that is initial at t equal to t and C is equal to C f understand. So, we can integrate this all we do is replace this with this term when replace this with this term.

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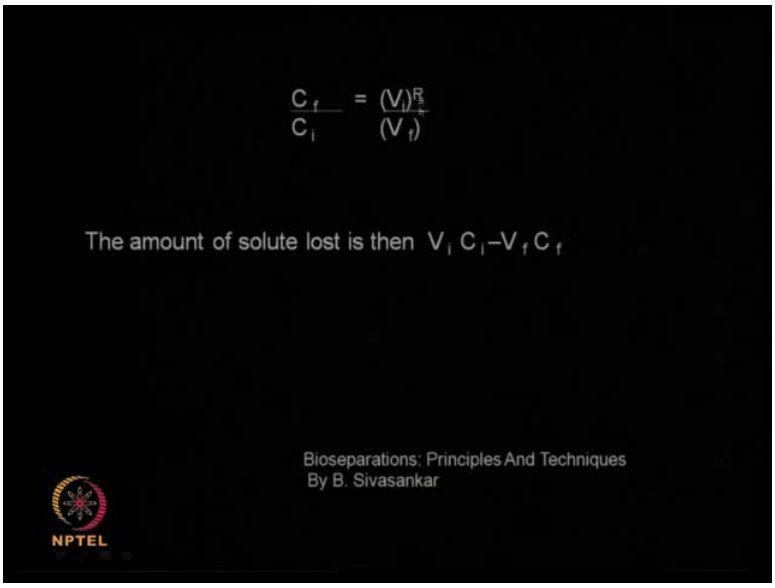

And then you integrate, so finally you may end up like this. C f concentration final, C i C on C entration initial, V i is an initial retentate volume, V f is your volume, then you have the R coming there, so the amount of solute that is lost V i into C i is initial minus V f into C f final. So, this is the total amount of solute lost in that period of time understood and some t time.

Now, if you want further details you may have to look into this particular references, where they have given this derivation and this particular slides are based on those derivation. So, we looked at some of the governing equations in both ultra filtration and micro filtration, and so we can use those equation to get a feel of what is happening to the process of membrane filtration.

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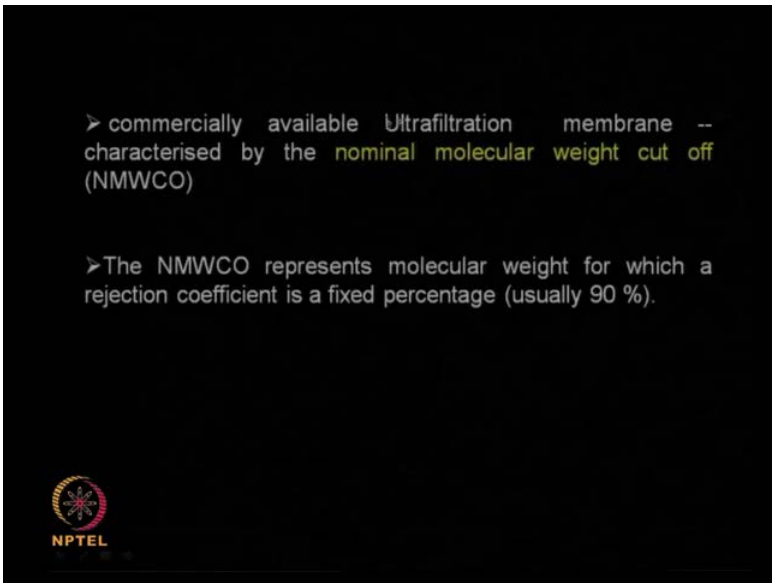

Now, let us move forward, now in ultra-filtration there is a term called nominal molecular weight cut off NMWCO; that means, the molecular weight cut off for which it is designed. So, if this give NMWCO as 20,000 dalton, so it will cut off at that value of 20,000 dalton. So, a molecular weights bigger than that will be retained molecular weight smaller than that will flow through.

So, if we have a NMWCO as 10,000 molecular weight greater than 10,000 will not pass through molecular weight less than 10,000 will pass through. So, when you are buying a membrane ultra-filtration membrane where they give a term called NMWCO, so it represents the molecular weight for which a rejection coefficient is a fixed percentage; that means, about 90 percent because we cannot talk 100 percent right that is why we give it as 90 percent.

So, there the molecular weight greater than that NMWCO will get retained or rejected, retain means we talked about 90 percent of it getting rejected, so retained or rejection are the same. So, I mean this particular number is characteristic for a ultra-filtration membrane.

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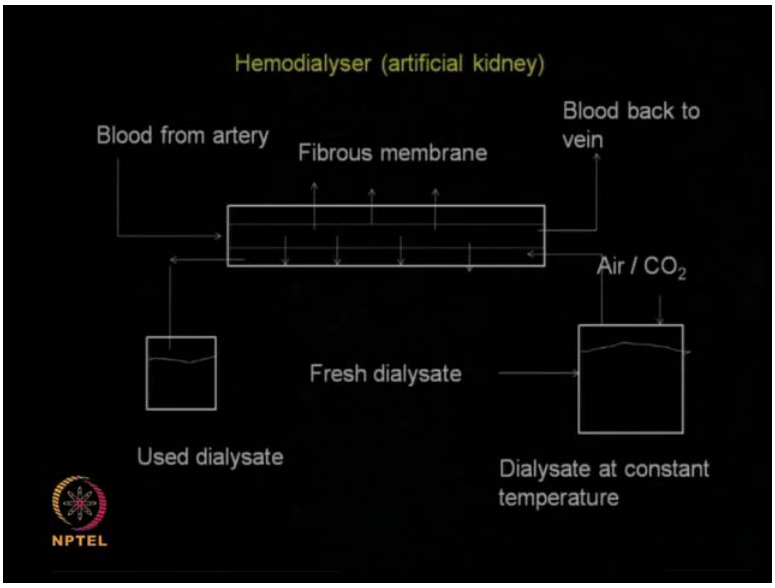

Now, let us go to another membrane technology, this is a very important membrane process. It affects a large percentage of people who are suffering from either kidney damage or inefficient kidney system where the urine does not separate out properly from the blood. That means, the salts in the urine are not separating properly or if it is a congenital disease; that means, there are children who are born with this type of problem.

Then they have to resort to hemodialysis and it is quite painful, they have to it is not physically painful, but the patients have to undergo this type of treatment every 1 week or 2 weeks or and so on actually. That means, the patient every week goes and spends about 2 3 hours in and an artificial kidney is attached to him or her and this particular instrument removes all the salts from the blood and makes it normal.

And we do not realize our kidney does this job every day, day in day out and people how have this problem either should get a kidney transplant. And now a day's getting a kidney transplant is impossible because there is large shortage of kidneys in India itself. Now, there is a very large shortage and so many of them will not be able to get kidneys, number 1, number 2 sometimes this is the kidney can body can reject the kidney.

You may have a kidney transplant, but the body can reject the kidney and then becomes totally useless. So, generally a kidney transplant within a relationship is always favorable because the rejection ratios are much, much low. So, if somebody who cannot get a

kidney transplant and who has a problem in getting the salts in the blood like, uric acid and other salts they may have to undergo this particular hemodialisis.

So, what is a hemodialisis, so there is a membrane it is a long tube fibrous membrane and then you have something called dialysate that is a fresh dialysate. It is nothing, but salts and water that is all. So, it is flowing and some it is flowing, because you apply some air pressure, now the blood from the artery comes; that means, from the patient it goes through this particular fibrous membrane. So, all the salts gets diffused and they go to the dialysate and the blood that is leaving will be free from all this salts. So, this is called the used dialysate which will have all the salts toxic salts present in the blood.

So, that is why this is called a artificial kidney. So, which a fibrous long tube here, you introduce fresh dialysate and here what you get is a used dialysate. So, it needs to be process, so that it gets converted into fresh dialysate. So, whatever toxic salts that are there which it has taken from the blood will be removed and then again it is put back. So, this is it looks very, very simple, but it saves thousands and thousands of a patients where problem with the kidney.

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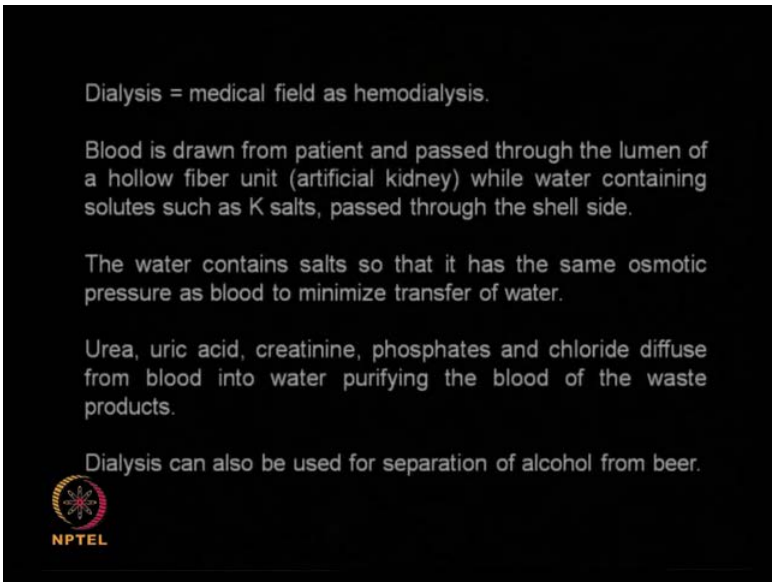

Let us look at what it does, so it is hemodialysis is a dialysis unit in the medical field, so we can use it even in your manufacturing process, where you are interested in separating out certain salts from certain solution. It can even be used for separation of alcohol from bear and so on. So, what is it doing the blood is drawn from the patient pass through the

lumen of a hollow fiber unit there is a long hollow fiber water containing solutes. That is called the dialysate such a potassium salts pass through the outer side, that is the shell side.

Why do you add salts to the water, so that it will also have same osmotic pressure as the blood, otherwise what will happen if there is an osmotic pressure water will start flowing in to the blood. You do not want that to happened understand, that is why you do not just pass water in the outer side of the fibrous membrane you also have salts.

So, that the osmotic pressure is balance and there is no water ingress into the blood. So, what happens then these two liquids flow urea, uric acid, creatinine, phosphates, chloride diffuse from the blood into water and your blood gets purified. Looks quite simple, but it does a fantastic job.

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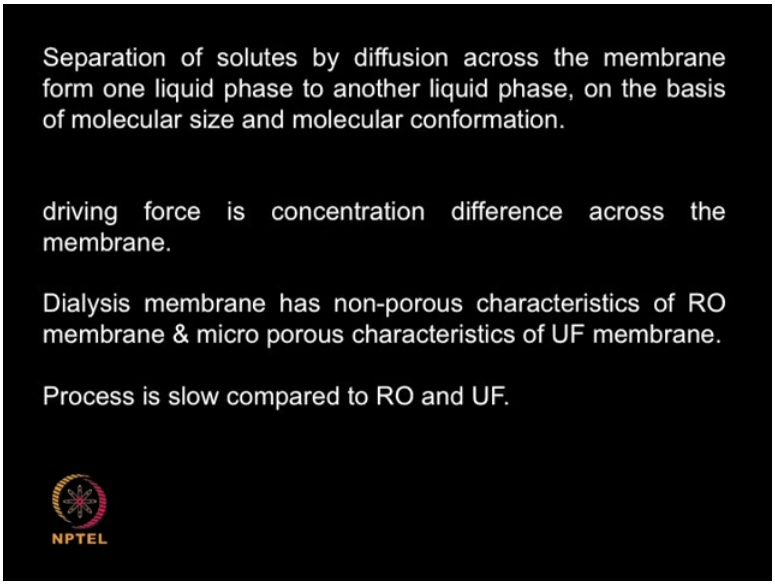

So, you can the separation of solutes generally happen because of the diffusion across the membrane from one liquid phase to another. So, it is based on the concentration difference. So, the blood has a very high concentration of all the salts and your dialysate has very low concentration of these, so the driving force is your concentration difference. So, the dialysis membrane does not have porous does not have non porous characteristics like RO or micro porous characteristic of UF.

So, it is in between both, it is not completely non-porous like reverse osmosis or it is not complete got so many porous like ultra-filtration. So, it is in between, so the process very slow, normally the patients who go for a this type of dialysis treatment have to spend 4 to 6 hours much a very, very long process. So, if somebody has do dialysis every month imagine the person has to spend more than half day lying down dialysis machine connected to the person.

So, if it can be spilled up then people will be very, very happy actually. So, there is lot of research opportunity is in trying to speed up this dialysis process also. So, how can one speed up? One way is to increase the surface area, but you cannot increase the contact area too much because the flow gets disturbed.

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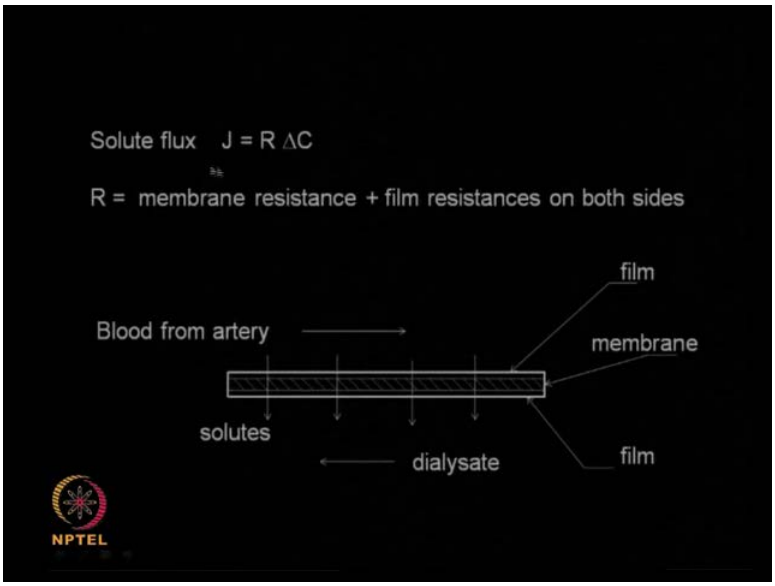

So, what happens there is a solute flux J which is equal to R, R is here resistance delta C is your driving force obvious right, now the resistance or many fold. Resistance because of membrane itself, resistance because of the film on the blood side, resistance because of the dialysate salts on the other side agreed. So, there are 3 resistance you need to consider R is made up of 3 resistance, so the blood is flowing dialysate is also flowing.

Although, I have shown it as countercurrent generally cocurrent is preferred, so, if you have the dialysis membrane that is going to be a film in the blood side, there is going to be another film in the dialysate side. So, the salts have to diffuse through these 3 films the film which is formed by the salts in the blood side, and the film that is formed on the

dialysate side and in between you also have the membrane material. So, the equation for the flux is given by this resistance multiplied by delta C delta C is your driving force concentration gradient.

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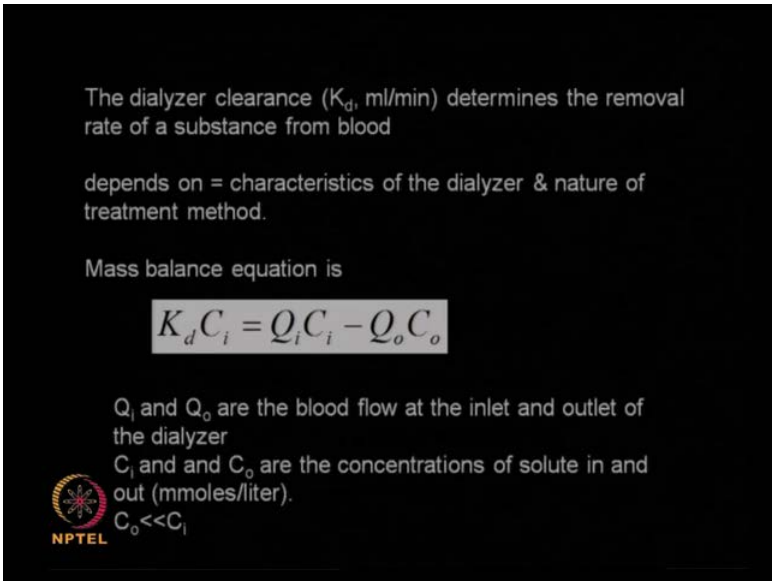

Now, there is something called dialyzer clearance; that means, it tells you how much the rate of removal of a substance from the blood, when you say rate of removal we will say there is always a time per minute or by a pre second per what. So, it depends on many factors characteristics of the dialyzer, nature of the treatment and so on. So, if you look at the mass balance for your particular solutes C you have K d that is your clearance, C i that is the amount of solute that is removed, that is equal to Q i into C i, Q i is the input blood flow that is at the inlet, Q naught is the outlet blood flow from the dialyzer agreed.

Obvious, C i is your concentration of the solute in C naught is the concentration out obvious. So, you have concentration of solutes coming in into Q and again you have concentration of solute leaving into Q this is equal to amount removed K d into C i. Generally, C naught will be much, much smaller than C i, because in your dialyzer the main goal is to remove the salts so; obviously, Q naught has to be very small no problem right.

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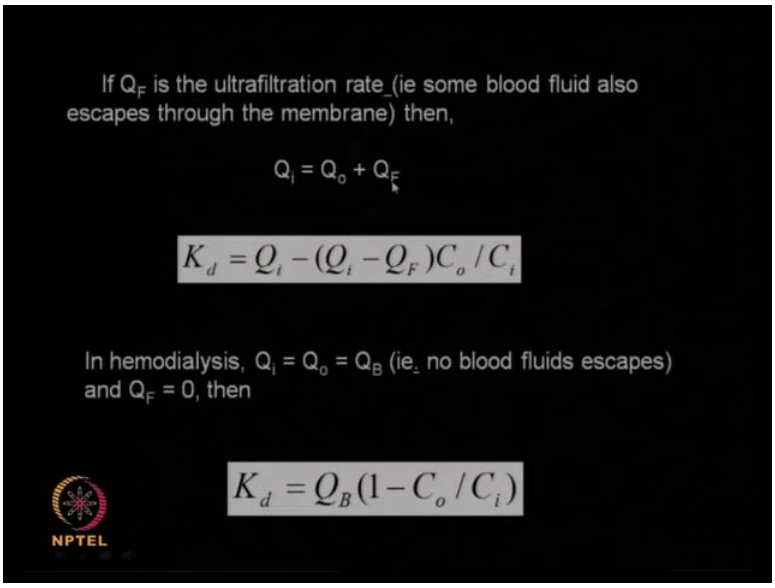

So, we can combine these equation if Q f is the ultra filtration rate that is some blood flow also happens; that means, blood escapes through the membrane and reaches your dialyzer. Then q i that is the amount of blood coming in will be equal to Q naught plus Q f, you do not want blood escaping into the dialysate right, but it can happen in some situations, so do not forget that it can happen. In generally we can assume some number. So, we can substitute all these and we get an equation for K d that is the clearance what is K d dialyzer clearance removal rate of a substance from blood.

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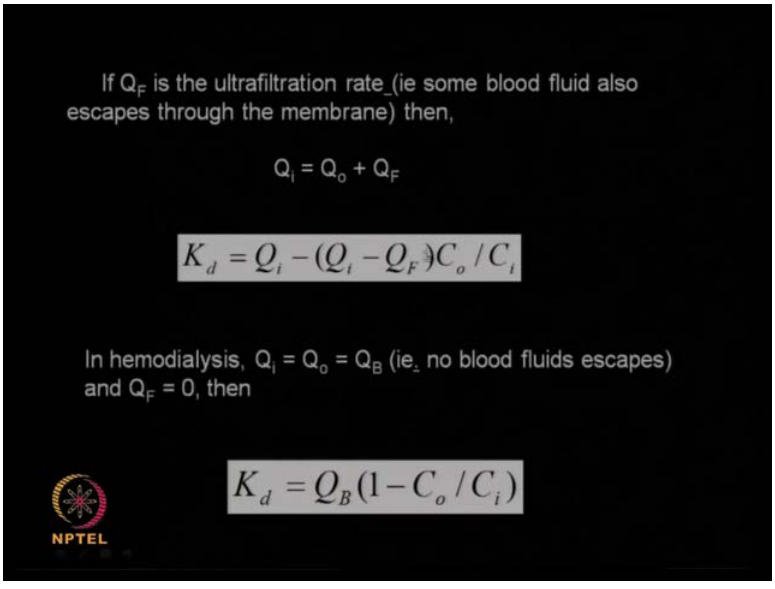

That is given by Q i that is the blood flow into the dialyzer, Q naught is the blood flow out leaving, Q f is the blood escaping through the dialyzer, C naught is the concentration of the salts entering your dialyzer, C i is your concentration entering, C naught is what is going on. When generally Q f is equal to 0, generally blood will not escape and then generally all these quantities are same; that means, Q f will be equal to Q f and so on actually.

So, a very simple equation comes out the clearance K d is given by Q b that is the amount of blood rate of blood flowing through the dialyzer, 1 minus C naught by C i, C i is the in let concentration of the solute, C naught is the concentration of the solute leaving the dialyzer. And generally C naught is greater than C i or less than C I, C naught will be less than C very, very small because we are trying to remove the salts right. So, C naught will be less than C i agreed. So, this gives you an idea about the clearance.

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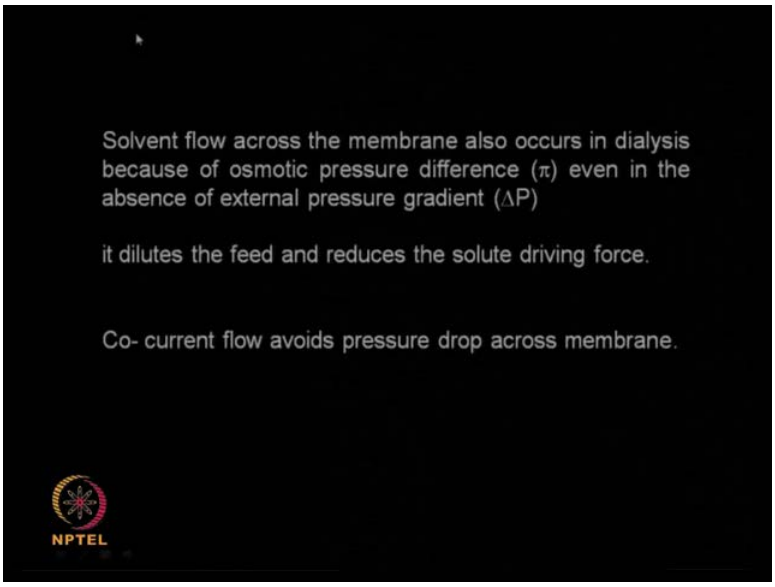

Now, solvent flow across the membrane also occurs in dialysis because of osmotic pressure difference. So, there is some osmotic pressure, so there is some loss of water and water may enter into your blood and so on. And generally we use a cocurrent type of flow to avoid a pressure drop across the membrane. So, these are some points which one needs to think about when the case of a dialysis.

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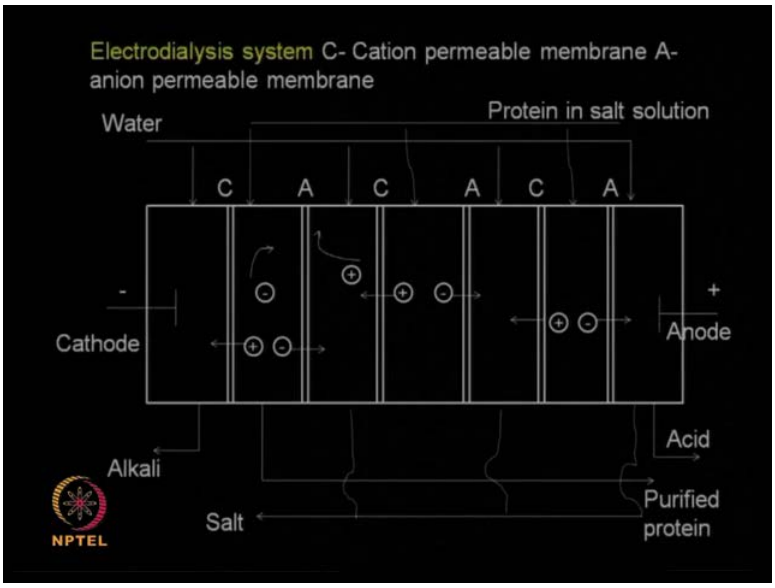

Now, let us go to something called electro dialysis, electro dialysis as the name implies electro we apply a very large potential difference. So, when you apply a large potential difference cations will go to where cathode, anions go to the anode. And they get separated out, because of the large electric field and we have cation favoring membranes, anion favoring membranes or selective cation selective membranes anion selective membranes.

So, in an electro dialysis you have many chambers or many compartments and each chamber is separated by one set of membranes. They are called ion selective membranes. So, you may have cation selective membrane, then you may have a anion selective membrane, we have again cation selective and so on. And then you have applying a very large voltage you see anode acid cathode here.

Now, imagine I have a protein under salt solution, when do you have a protein under salt solution, especially if you are doing salting out, we do salt out you have lot of ammonium sulfate. So, you have protein solution will also have salt solution, so first step is to remove all the salt. So, electro dialysis is very good because salt is ammonium sulfate, it will nicely ionize and I can put a large voltage and I will be able to separate them all.

That is the whole idea and so that protein can be recovered in water, now suppose I have a protein in salt solution, then I am passing water. So, water is passed into alternate

chambers protein is passed into alternate chambers. Now, you are applying a very, very large voltage and then you have anion selective membranes, cation selective membranes alternatively. what will happen? Look here now your salt gets ionized agreed.

So, the pluses want to go there, so if it is a cation selective membrane, it will nicely go there. Now, imagine a minus will not be able to go there, so minus has to who which wants to go to the anode and these anion selective membrane, so the minus will go here. Now, this plus wants to go there, but it cannot go because there is a anion selective membrane, so it will sick here. So, what will happen you have alternate chamber with plus and minus and the alternate chambers will be pure free from salts.

So, you will have alternate chambers without any salt and alternate chambers with high concentration of salts. So, what will happen you will have protein in water, in alternate chambers, it will be free of salt. And you will have high concentration of salts in the alternate chamber understood. So, I can nicely recover my protein from the alternate chamber which is in water medium and all the salts would have gone to the alternate chambers.

This is the how system by which electro dialysis does it is job very interesting. They got lot of advantages, disadvantages. It is very good for doing this, but there is heat generation because you are applying high voltage, energy consumption is very high, membrane material you need to replace from time to time because of fouling and so on actually.

You know there are different types of fouling happening here, erosion of the membrane surface all is happens actually. But, it is a good system to have because you will have alternate chambers without any salt; that means, pure water and alternate chambers you will have very highly concentrated salt present actually. So, that is the advantage of this type of electro dialysis.

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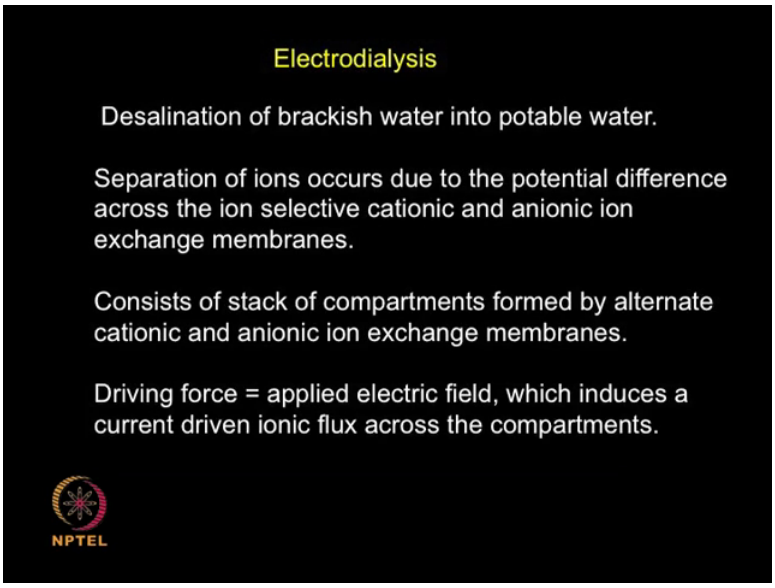

Now, we can use it for desalination of brackish water, so what we can do is we can use electro dialysis all the slurry of salts will be in the alternate chambers and remaining alternate chambers will be free of the salt. And so we will get drinking water separation of ions occur due to the potential difference across the ion selective cationic and anionic ion exchange membranes as I mentioned actually.

So, it will have a stack of compartments sometimes you will have 20 30 stack actually, and each stack will have alternating membranes, like cationic, anionic, cationic, anionic and so on actually. So, the driving force here is what there is an applied electric field, now this induces a current and there is a flux across the compartments.

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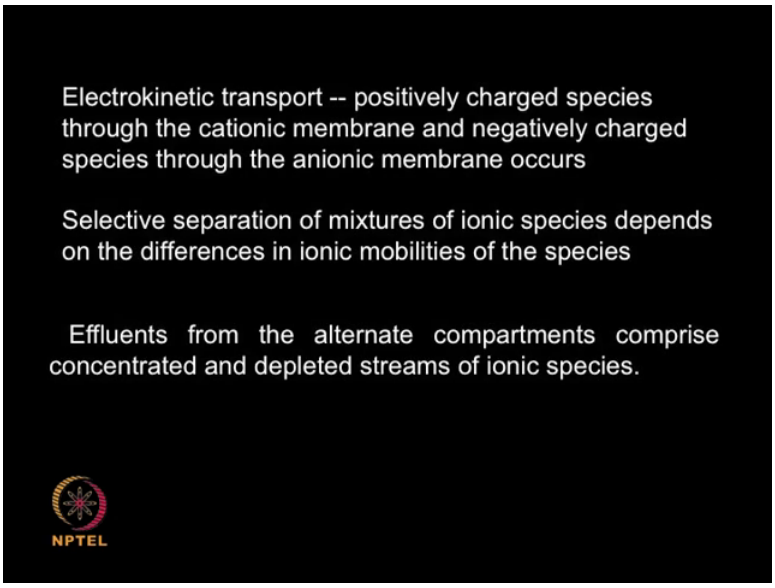

This is what happens in an electro dialysis. So, positively charged species goes through the cationic membrane, negatively charged species go through the anionic membrane because these membranes are very selective. So, this other type of charged material will not go to the non-selective membrane. So, we can use it for selective separation of mixtures of ionic species, depends on the difference in the ionic mobility is also.

So, some smaller ions may be able to go diffuse much faster, so they are much more mobile larger ions and will take much longer times. So, we can use it as a function of a mobility as well. So, the effluents; that means, the liquid that is coming out alternate compartments will be concentrated of the ionic species and depleted of ionic species. So, will have concentrated, depleted, concentrated, depleted and so on actually, so that is the advantage of a this particular setup.

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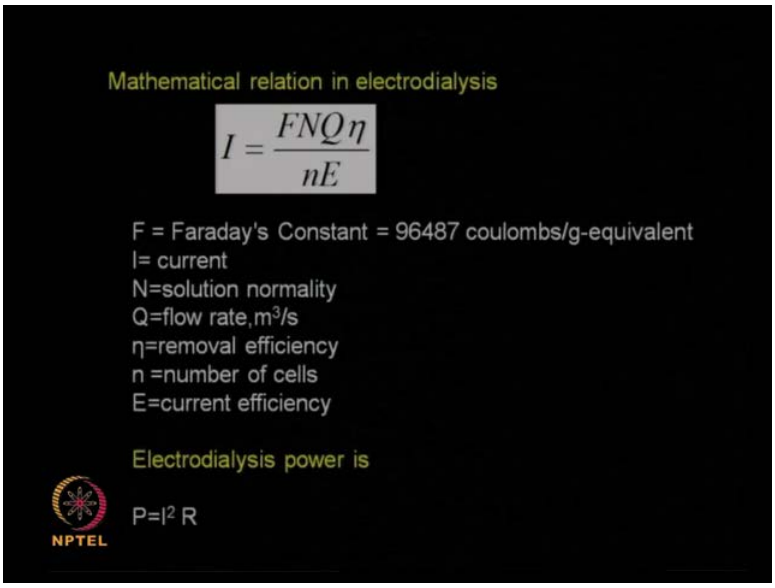

So, there is a mathematical relation which connects the current that is flowing with the charge partial details you know. So, you have current I is equal to this is a constant it is called faradays constant, N is the solution normality, Q is your flow rate eta, is your efficiency, n is your number of cells E is your current efficiency. So, eta is a removal efficiency E is a current efficiency do not forget. Now, f is the faraday constant, so this is the normal number for the faraday constant.

Now, using this equation I can calculate if I know the flow rate, if I know efficiency factors little bit here. If like this efficiency, and this efficiency, and n gives you number of cells. So, if I know all these I may be able to calculate what will be I; that means what will be the current. Now, there is another term which is very important that is called the electro dialysis power; that means, how much power should I put in for this particular operation.

So, if I calculate my current from this equation I can substitute here and if I know the resistance of the entire setup of n cells. That means n compartments, when I say cells it is n compartments I will be able to calculate the power. So, it will give me idea of the power requirements for performing an electro dialysis type of a operation.

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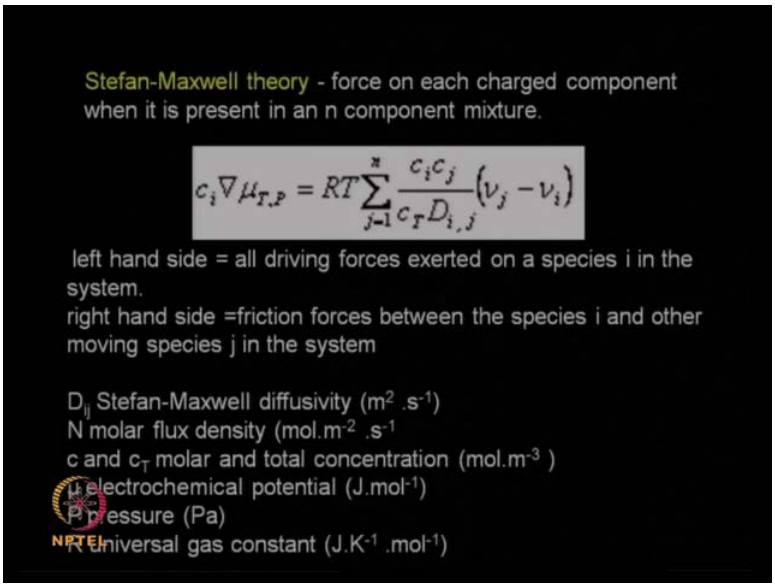

There is another equation which also gives you a flavor of the process that is taking place, that is called the Stefan Maxwell theory. So, that gives you force on each charged component when it is present in an n component mixture. So, we have it is summation because when you have n component mixture, each component will undergo or experience of force because of another component.

That is why you have summation here we have c i c j, c j will be running from 1 to n, small n where small n is the number of components were D i j is a Stefan Maxwell diffusivity.

So, left hand side is all the driving forces exerted on a species right hand side is related to all the friction forces. Now, you have the concentration c t is your total concentration, P is the pressure, R is your universal gas constant, T is your time and so on. So, this tells you what is the force that a particle of certain charge experiences if the presence of many particles that is n particles.

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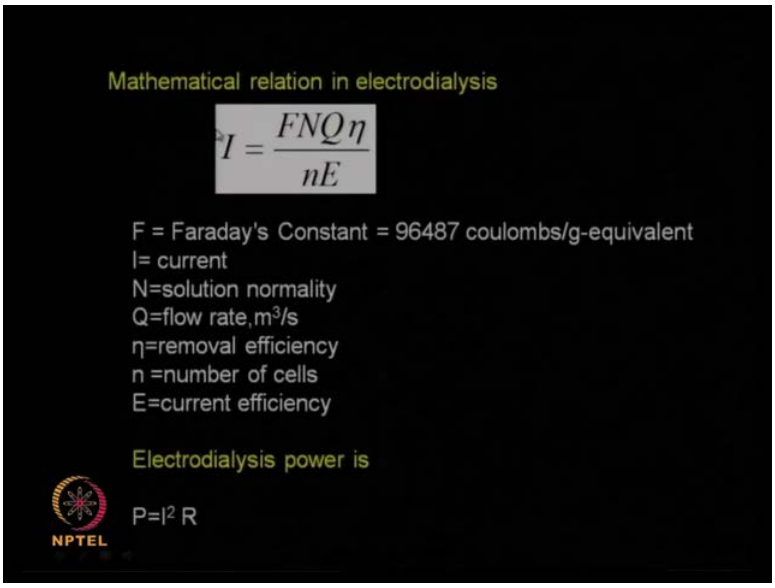

We will not go too much into that is too much of a fundamental study, whereas this equation may be much more useful which gives you an idea about the amount of current. When you have n compartments, when you know the efficiency of the removal a process, when you know the efficiency of the current, when you know the solution normality, and when you know the flow rate. This equation is much more useful and of course, this gives you an idea about the power, so this equation is also pretty useful.

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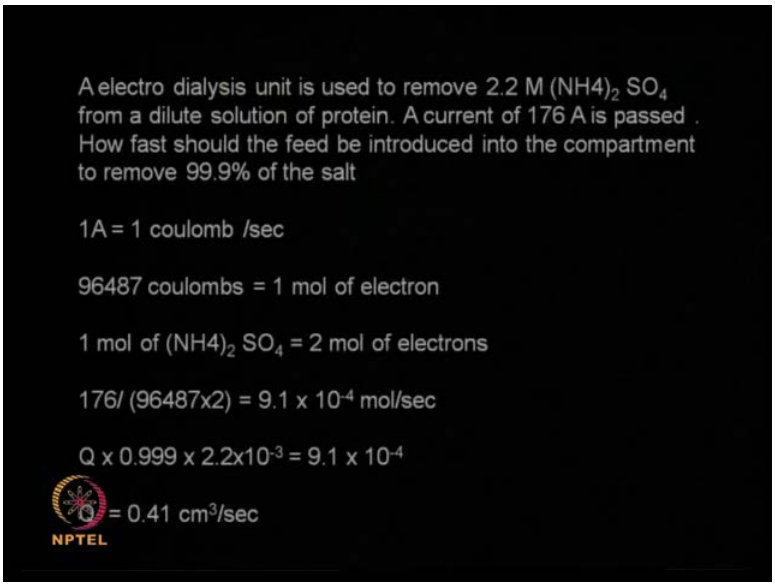

Now, based on this equation, let us look at a problem, so I have a electro dialysis unit is used to remove 2.2 moles of ammonium sulfate from a dilute solution of protein. So, you are passing a current of 176 ampere, how fast should the feed be introduced into the compartment to remove ninety 99.9 percent of the salt. So, I want to remove 99.9 percent of the salt, I want to know Q and the amount of salt solution that is flowing in contains 2.2 molar ammonium sulfate, and I am passing 176 Amps, so how do you solve this?

So, we know 1 Amp is equal to 1 coulomb and 96 487 coulombs is 1mole of electron, if I take 1 mole of ammonium sulfate that will be 2 moles of electrons right SO 4 double minus, so you will have to electrons. So, all you need to do is substitute them into this, and then will be able to get the value for Q, now Q is Q into 0.99 is the amount of salt that are removing. So, from there we will be able to calculate Q understand. So, the problem is I have so many molars of salt solution flowing at a particular rate.

And I want to remove so much of the salt from a solution I am passing so much current so what should be my flow of the solution. So, this comes from the ionization of the salt in this particular case ammonium sulfate NH 4 2 SO 4. So, there will be 2 electron flowing into that whereas, if it is sodium chloride it will be one electron flowing into that, so do not forget that. So, that is show you calculate the whole problem.

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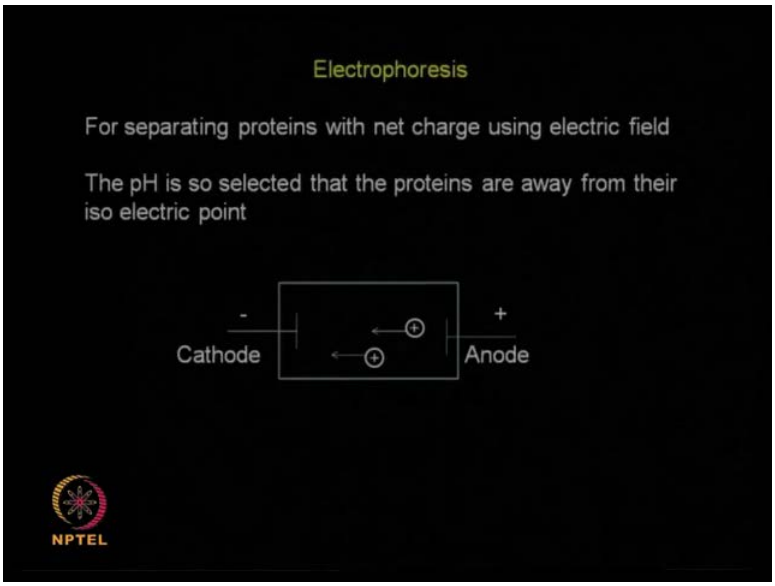

Now, let us go to again process which makes use of a voltage that is the electrophoresis, we all have come across this in analytical lab, where you want to separate proteins of

different charges. So, all proteins have some charge, why there are nitrogen and COAH, what is COAH that is the acidic group? So, there is going to be COO minus that is the charge sometimes nitrogen will have n plus, so that is a charge. So, proteins will always have charges do not forget that. So, there is one pH at which proteins will have net 0 charge, and that is called the iso electric point.

So, if we are operating away from iso electric point proteins will have charge. So, if I apply a voltage, proteins will start moving. So, if I have proteins of different molecular weight or different sizes and they are all plus I am applying a large voltage they will all get attracted to the negative minus correct cathode. Now, this P at which they get attracted will depend upon the mobility; that means, it will depend upon the size. So, I can achieve a separation based on the size, this is how electrophoresis is work you agree.

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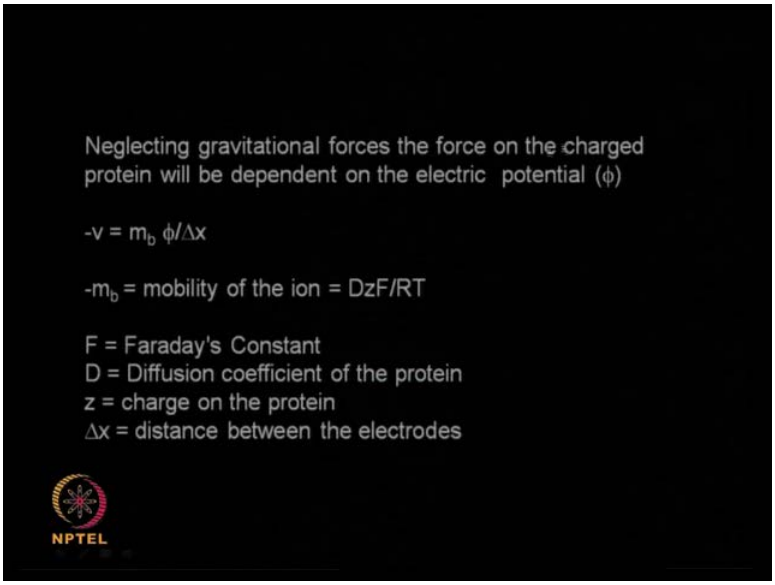

Now, if you neglect gravitational forces, the force on the charged protein will depend on the electrical potential; that means, how much potential I am applying and the mobility divided by delta x, delta x is the distance between the 2 electrodes. So, if the delta x is very, very large d the mobility the rate this speed at which the protein or the velocity at which the protein is moving will get decrease.

If I electrical potential is large the speed at which the protein is moving will be high and in the mobility is very large, then the speed at which the protein is moving also will be very high. Now, this mobility is again dependent on several factors D the diffusion

coefficient z charge on the protein F is your faraday constant R T universal constant and t is normal. So, you see here the mobility we can see is a function or diffusion coefficient mobility is function of a charge.

So, if I have very large charge protein, it will move very fast to words the cathode. If the charge is very low it will move slowly, so if I have a protein we charge 2 minus plus 2. And if I have a protein with plus 1 charge the plus 2 charged protein will move faster right.

Then the plus 1 charge protein and but of course, you have something called diffusion coefficient, if the diffusion coefficients are different between the proteins. Then that will also affect the mobility, so only not only the charge on the protein that is an important, but also the diffusion coefficient.

So, sometimes if you have a very large protein the diffusion coefficient may be very poor, then the movement will be retarded; that means, it will be moving much slowly. Whereas, if you have a protein which is much smaller then it will be moving much faster; that means, diffusion coefficient will be much larger than the mobility also will be larger. So, the size of the protein matters the charge on the protein matter, so both matters actually understand.

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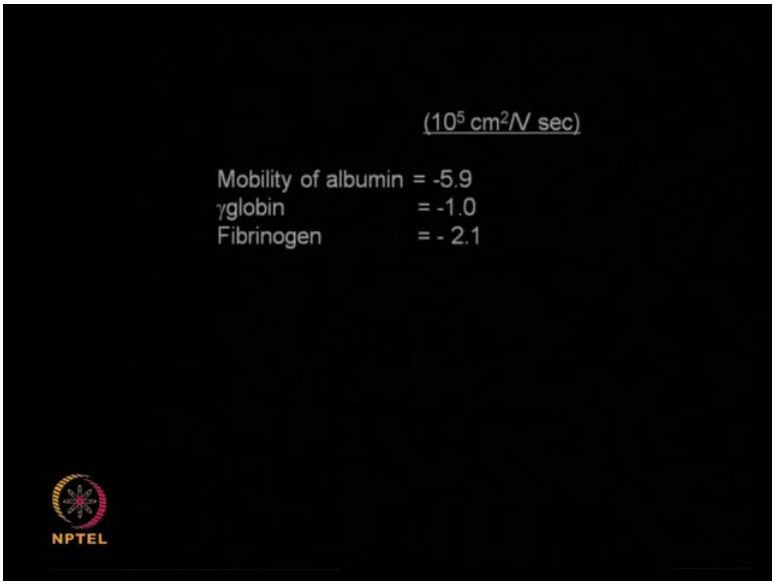

So, look at mobility you have for albumin 5.9 gamma globin 1; that means, it is almost 6 times lower fibrinogen minus 2.1. That means, albumin is 3 times or 2 times faster than fibrinogen and fibrinogen about 2 times faster than globin. So, you see large difference in the protein mobility.

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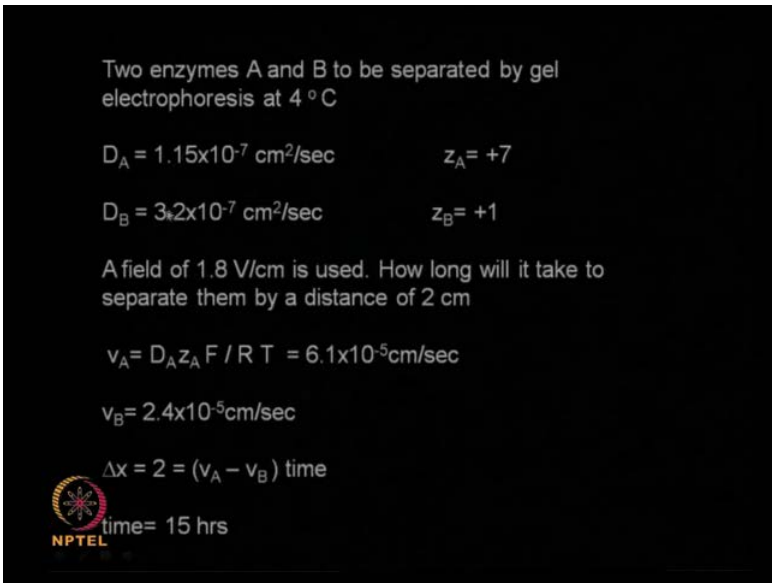

Let us look at a small problem using this approach, I have 2 enzymes A and B to be separated by a gel electrophoresis. Generally, we use this particular approach electrophoresis for separating protein, I am doing it at 4 degree centigrade. Now, the diffusion coefficient of protein or enzyme A is this much the diffusion coefficient of enzyme B is this much; that means, this has got higher diffusion coefficient than this now this is got higher charge see this is got 7 this is got only 1.

So, because of charge this protein may move faster, but because of diffusion cohesion this protein will move faster. So, this is a equation the velocity, diffusion coefficient, the charge, faraday constant divided by R into T. Now, we are applying a field of 1.8 volt per centimeter, how long it will take to separate them by a distance of 2 centimeter. So, how long it will take? So, that they are 2 centimeters away, so now, I can calculate velocity A, I know D A I know z A charge I know faraday constant I know RT. So, I can get V A agreed, so for V B, you have D B z B F R T, so I get V B.

Now, this protein is going at a velocity of 6.1 into 10 power 5 minus 5 centimeter per second, this protein is going at 2.4 10 power minus 5 per second. So, velocity A minus

velocity B into time will be equal to distance correct, velocity into time is distance agreed. So, V A minus V B into time will give me distance, distance is 2 centimeter, I want to push them 2 centimeter apart. Now, V A is this much V B is this much, so time comes out to be 15 hours, so I run this electrophoresis for 15 hours.

So, that the 2 proteins get separated by 2 centimeter based on the protein charge, based on the diffusion coefficient of the protein correct. Now, this is how you use to calculate? how long should I apply this particular electric field? So, that the proteins get separated by say 1 centimeter or 2 centimeter or 3 centimeter and so on. So, this problem very simple problem tells you in the electrophoresis system, how do you separate out proteins?

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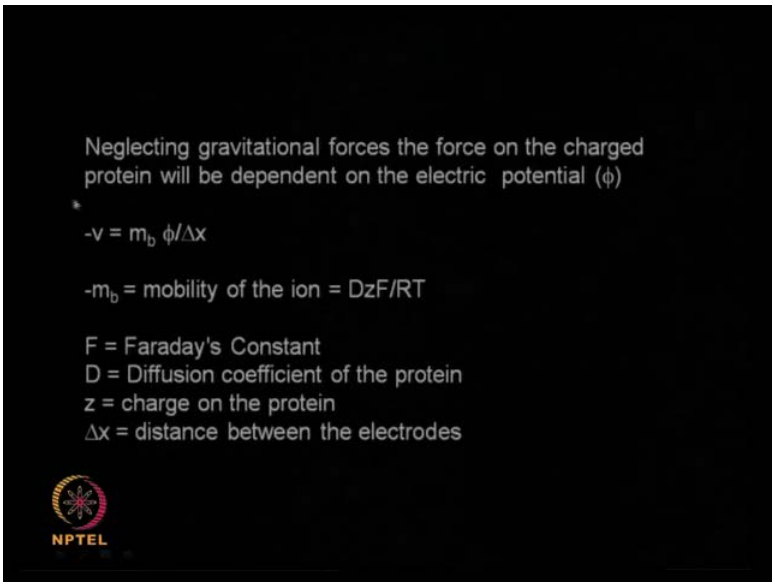

Now, the simple equation, so you have velocity, we have the mobility, we have the electric potential or the force we apply divided by the delta x.

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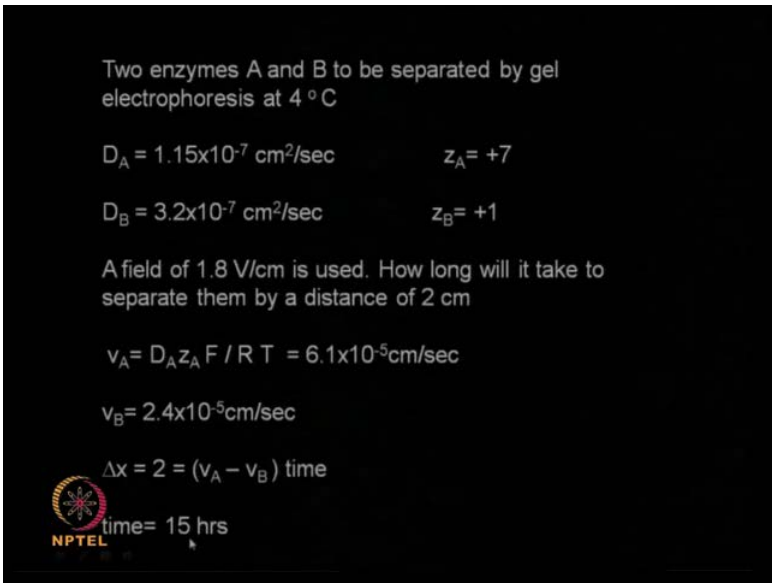

Such a simple equation we make use off and calculate what should be the time require to separate these 2 proteins by 2 centimeter apart?

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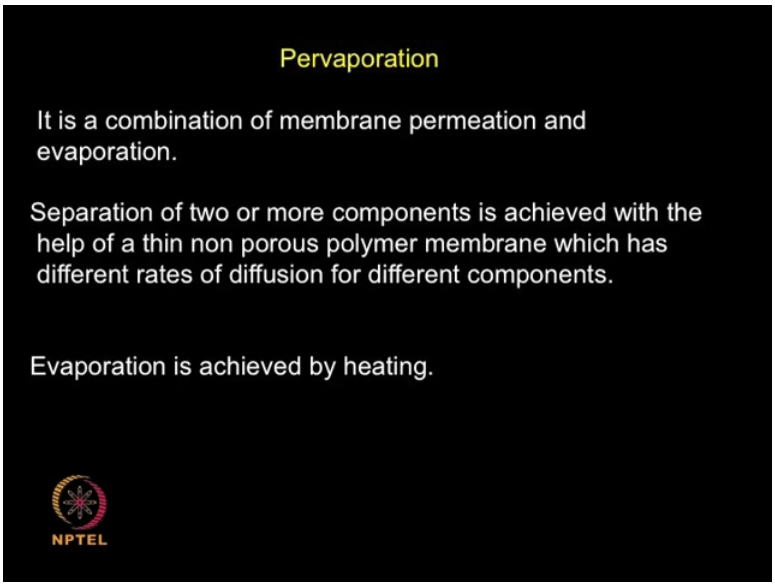

Now, let us look at another membrane separation process that is called pervaporation is a combination of a permeation and evaporation. So, we can separate 2 or more components with the help of a very thin pervaporation membrane. So, if one component has certain rate of diffusion, another component has another rate of diffusion these 2 can be separated. Pervaporation is not based on filtration, because there are no holds in the

membrane, the solute gets sort of dissolved inside the membrane it gets diffused and it comes on the other side.

So, you have a vapor on one side, how do you achieve vaporization, you heat it out. So, there is going to be vapor on one side, then that solute gets dissolved in the membrane, it travels through the membrane. And then on the other side it is collector and it becomes a liquid. So, what is the driving force you apply a vacuum on the other side, so you have a heating on one side and you have a vacuum on other side and the membrane does not have any force or holds.

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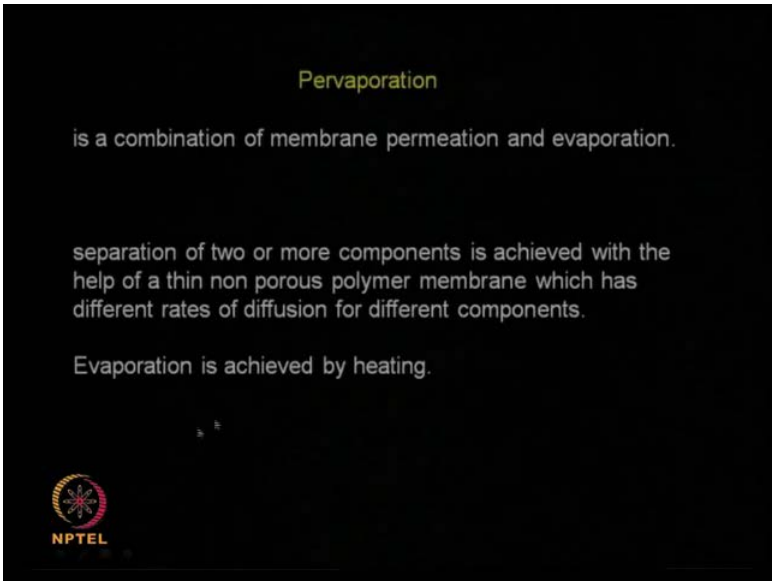

This is what pervaporation is, it is a combination of permeation and evaporation.

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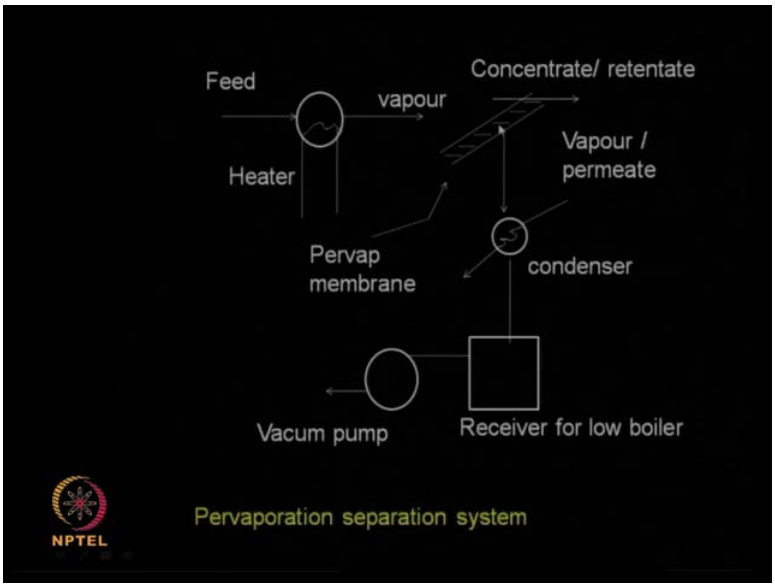

How does a setup look like, simple one very simple you have a pervaporation membrane we have here feed heat of the feed, so that it gets vaporized. So, it comes here and you are applying a vacuum on other side. So, that is the driving force, so the vapor gets dissolved in the membrane material, it travels or diffuses through and the vapor comes out on the other side. It is condensed in the condenser and you collect the liquid, so here you are applying a heating. So, that the feed gets vaporized hear.

You are condensing the vapor and the driving force is your vacuum here. And there are no pores in the membrane, so the process is permeation and evaporation, so permeation is like diffusion not like a filtration here. So, you have a hydrophilic membranes, hydrophobic membranes that is membranes which favor a particular type of material. If you want to recover only hydrophilic solutes then you go for hydrophilic membranes, if you want to recover hydrophobic materials then you have a hydrophobic membrane.

So, if you have a hydrophilic membranes here hydrophilic material will permeate through or diffuse through. If you have a hydrophobic membrane will have a hydrophobic material will permeate or diffuse through. So, that is the difference. So, this process is very good, it is being used quite large for concentrating fruit juices or dairy products, it can be used for separating water from alcohol.

So, we can get 100 percent alcohol here, so, the membrane will pass only water through and as you know we cannot get 100 percent water by distillation, because water forms a

azeotrope and distillation is not possible, so in such situation we use pervaporation. If we have fruit juices and I want to remove some water, I cannot heat it because fruit juice will get totally chard or burned. So, here you will have here hydrophilic membrane and only water will go away, so this side you will get more concentrated fruit juice. So, this process is already being commercially practiced in many places, especially for food as well as for concentrating as well as for a water removal as so on. So, we shall continue more on this pervaporation process in the next class.