Novel Separation Processes
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Lecture No. # 29
Surfactant Based Separation Processes

Good morning everyone. So, we were discussing about the gas separation by membrane based processes, and in the last class we have seen the various modelling aspects of configurations various configurations of gas separation, for example the completely mixed up model, the cross flow model and the counter current model.

Now, using a now for last 2 cases for the complete mixing case, and the counter current case and the cross flow case, the governing equation will be the ordinary differential equation, because the flow is assumed to be a flat flow. On the other hand case of completely mixed model the c s t r model is assumed to be valid because the feed composition is assumed to be uniform either permit chamber as well as in the feed chamber.

So, therefore it is easier to solve the governing equations for the completely mixed model, and we have just looked one example typical example of gas separation using the completely mixed model how to do the calculations. Now, in today's class we will take one more example to solve this particular case, then we will move on to the next topic of our syllabus that is the surfactant based separation processes.

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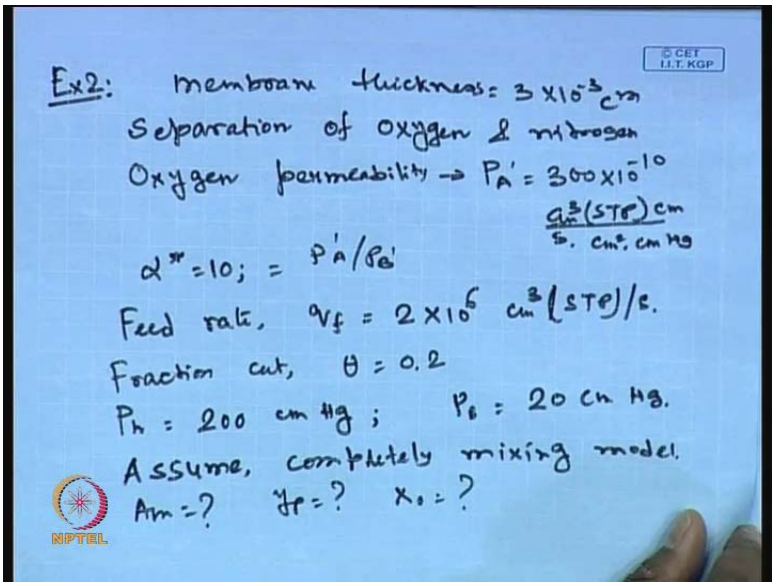

So, these problem let us look into example 2 for the gas separation case, in this case it is desired to find out the membrane area, we are using a membrane thickness is given it is 3 into 10 to the power minus 3 metre centimetre, and with oxygen permeability it is a case of oxygen separation of oxygen and nitrogen. separation of oxygen and nitrogen, the oxygen permeability of the with respect to membrane is given is P a prime is 300 into 10 to the power minus 10 centimetre cube at STP, centimetre divided by second centimetre square centimetre of mercury, it is given an alpha star is given as 10, that means the oxygen permeability will be 10 times higher compared to the you know what is alpha star? Alpha star is basically P a prime by P b prime.

So, oxygen permeability is 10 times higher compared to the nitrogen permeability through the membrane. The feed rate is given as q f is equal to 2 into 10 to the power 6 centimetre cube at STP per second, the fraction cut theta is given as 0.2, that we are expecting to get 20 percent of the feed coming to the permeate, the pressures are given feed side pressure is maintained at 200 centimetre of mercury, and lower side pressure that is the permeate side pressure is maintained at 20 centimetre mercury, and we assume the completely mixed up model completely mixing model we have to find out the membrane area that is required for this purpose permeate composition that is y P mole fraction of oxygen in the permeate, and reject composition that is X naught the mole fraction of the oxygen in the reject stream.

So, these were the so this is the problem so given this problem we have to find out the membrane area the permeate concentration, permeate composition and reject composition

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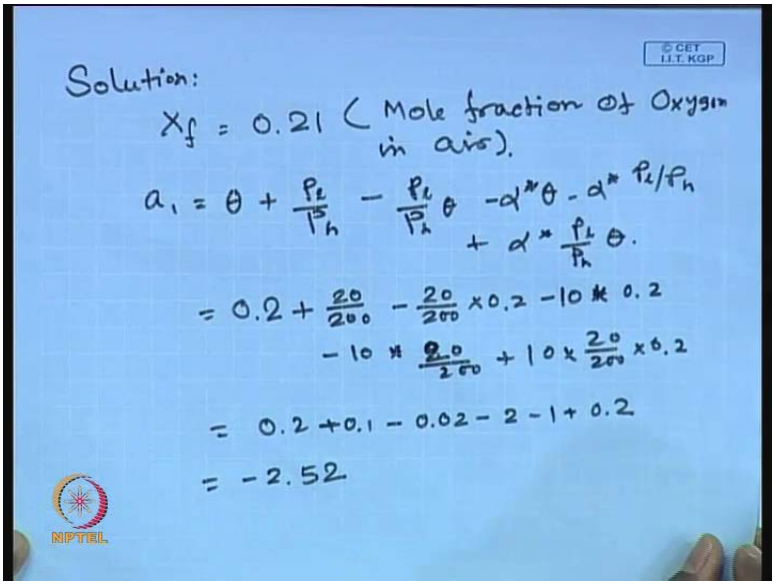

so the whole system can be characterised, now let us look into the solution, the solution is that your feed composition is known because it is a case of air oxygen and nitrogen the mole fraction of oxygen in air is 0.21.

So, we take x f as 0.21 that is the natural mole fraction of oxygen in air, so a 1 is given as theta, plus P l by P h, minus P l by P h times theta, minus alpha star theta, minus alpha star P l over P h, plus alpha star P l over P h times theta. So, if you put various values these turns out to be 0.2 divided by plus 20 by 200, minus 20 by 200, into 0.2, minus 10 into 0.2, minus 10 into 0.2, 10 into 20 by 200, plus 10 into 20 by 200, into 0.2 so these turns out to be 0.2, plus 0.1, minus 0.02, minus 2, minus 1, plus 0.2, so it turns out to be minus 2.52 so that is the value of constant a 1 given with the given conditions.

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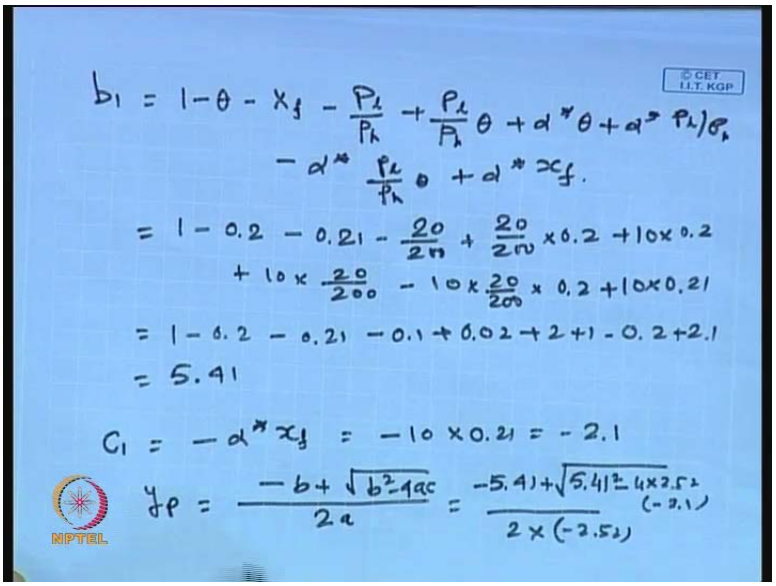

Now, let us calculate the variable b 1, is given as 1 minus theta, minus X f, minus P l over P h, plus P l over P h times theta, plus alpha square theta plus alpha star P l over P h, minus alpha star P l by P h times theta, plus alpha star X f, now you put different values so it becomes 1 minus, 0.2, minus 0.21, minus 20 divided by 200, plus 20 divided by 200, into 0.2, plus 10 into 0.2, plus 10 into 20 divided by 200, minus 10 into 20 divided by 200, into 0.2, plus 10 into 0.21 is the feed composition is 21 mole fraction of oxygen.

So, it becomes 1 minus, 0.2, minus 0.21, minus, 0.1, plus 0.02, plus 2, plus 1, minus 0.2 plus 2.1 and the total comes out to be 5.41. Similarly, you can calculate the parameter c 1 and the parameters c 1 is nothing but alpha star times x f, and this is minus 10 into 0.21 so it becomes minus 2.1, and you can get the expression of y P, that is the composition of permeate so it is minus b, plus under root b square minus 4 a c, divided by 2 a, so if you put all the values it turns out to be 5.41, plus 5.41 square, minus 4 into 2.52, into minus 2.1, divided by 2 into, minus 2.52.

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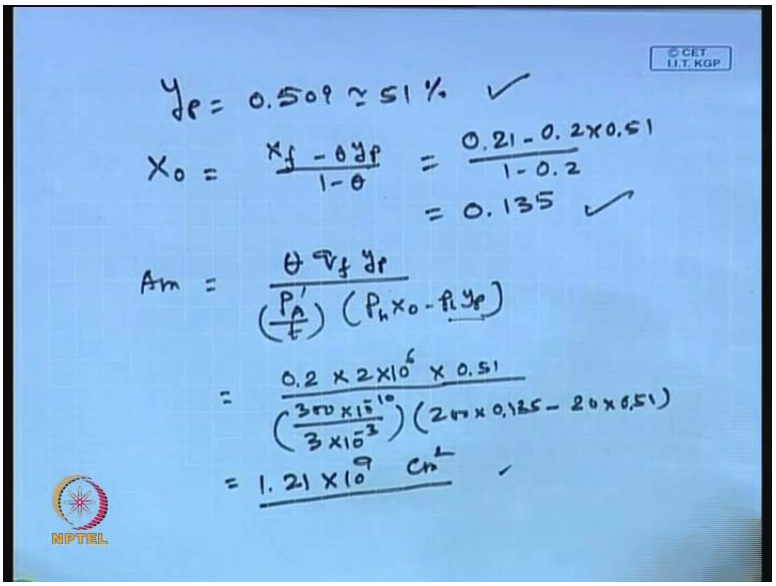

and the value of y P turns out to be 0.501, that means almost 51 percent, so you will be having a composition in the permeate which is rich in oxygen to the tune of 51 percent compare to nitrogen. So, x naught is the composition in the reject stream that is nothing but x f, minus theta, into y P, divided by one minus theta, so this turns out to be 0.21, minus 0.2, into 0.51, divided by 1 minus 0.2, and these turns out to be 0.135, and a m the membrane area if you look into the formula this was theta, into q f multiplied by y P, divided by P a prime over t, that is the thickness of the membrane, P h times x naught, minus P l times y P, which is the pressure difference, which is the pressure difference across the membrane these are partial pressure in the of the of oxygen in the feed stream, this term is the partial pressure of oxygen in the permeate stream, and if you put the values theta was 20 percent, so it is 0.2, into 2 into 10 to the power 6, 2 into 10 to the power 6, that was given into 0.51, divided by 300, into 10 to the power minus 10, divided by 3, into 10 to the power minus 3, that is P a prime by t, 200, into 0.135, minus 20 into 0.51.

So, this membrane area turns out to be 1.21, into 10 to the power 9 centimetre square, so you can find out the various parameters, you can find out the permeate composition, you can find out the reject composition, that means initially you were having in the feed 21 percent oxygen at the end of the operation in the reject stream we are going to get 13.5 percent of oxygen, that means the feed stream or the reject stream has been stripped away oxygen and the permeate stream is enriched by oxygen, and the for to achieve this

separation we have to provide a membrane area of 1.2, into 10 to the 9 centimetre square, that much of membrane area 1 has to provide.

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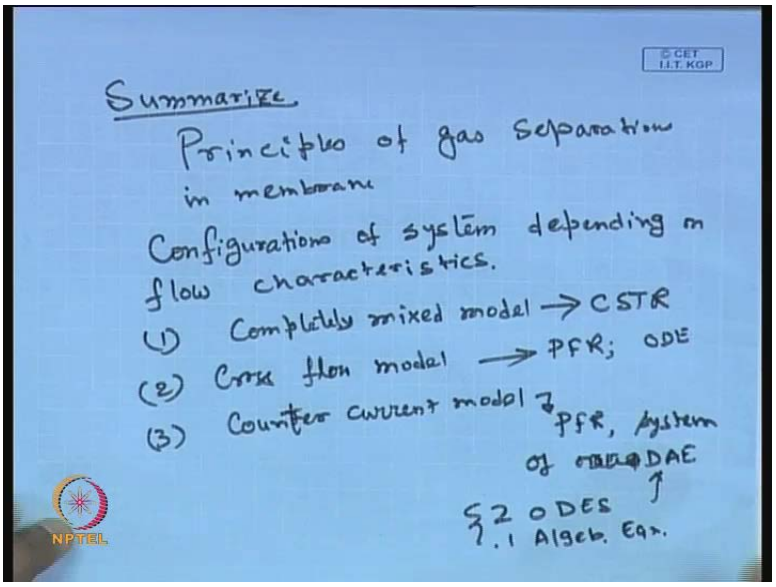

So, therefore we have if we summarise whatever we have done till now on gas separation is we talked about the principles of gas separations using membranes, we talk about the mechanism and things like that, and then we looked into various you know configurations of the flow depending on the flow characterisation, configurations of system depending on flow characteristic, first one we got the completely mixed up model completely mixed model, secondly we got the cross flow model, third we looked into the counter current model, we did not look into the co current model because counter current model is generally more efficient compared to the co current model, so there is you know the popular operation is counter current configuration.

Now, in completely mixed up model the assumption it is that it is like a C S T R that means the solutes are completely mixed up in the permeate stream and completely mixed up in the feed stream, so therefore there is no profile of solute concentration in the feed chamber or in the permeate chamber, they are uniform throughout the volume. Next one is the cross flow model here we found out that there are you know there it is like a plug flow reactor, and the concentration of the solute will vary as the as a function of membrane area or the length of the module.

So, therefore the governing equations were O D E and this case is much simpler and we got almost an analytical solution in our model, and in the count of counter current model it is entirely a it is like a plug flow reactor that means at every location of the membrane length the concentration of the of the solute will be varying, and you will be having a system of ordinary differential equation O D E plus D A E, that means ordinary differential equations plus you know it is called the D A E system differential algebraic equation, that means it consist of 2 O D E's for a binary system and 1 algebraic equation.

Now, these equations were solved using runge kutta 4 method, and one can have numerically one can find out what will be the concentration of the solute or the or the desired species along the membrane length, and one can find out the various composition of the reject stream, permit stream, membrane area required so on so forth, so that gives roughly an idea how the gas separation using the membrane based separation process can be modelled, and how the systems can be designed as far as from the engineering point of view.

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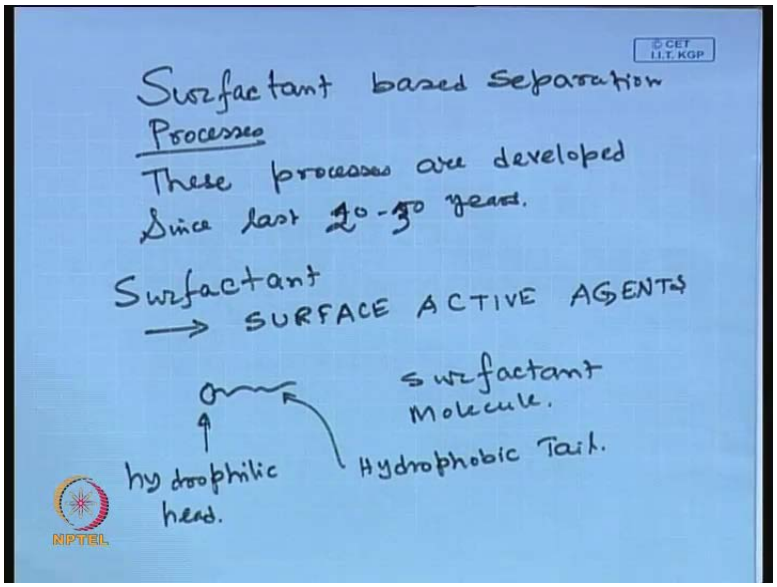

So, next we go to the next topic that is the surfactant the separation process, that is very important this is a type of novel separation processes, surfactant based separation processes and these processes are generally developed in the last 30 to 40 years, may be maximum up to 50 years, so these processes are developed since last 40 to 50 years in fact even less than that it will be from last 20 to 30 years, and most of them are have

been found out that in the laboratory scale they are highly feasible, but in the plant scale or in the pilot plant scale people are the research is ongoing how to implement them how to scale them up.

Now, these surfactant based separation processes are basically depending the main major characteristic of these processes are the efficiency of this processes are depending on the typical properties of the surfactants, so let us look into what is a surfactant? Surfactant is nothing but a surface active agent, there are some typical properties of surface active agents and the first property is that when you put the surfactant when you the surfactants will be having a hydrophilic head and a hydrophobic tail, that means these are typical surfactant molecule it has a hydrophilic head and it has a hydrophobic tail, that means this hydrophilic head likes the water environment it is it is water loving group, on the other hand the hydrophobic tail is water repelling group it does not like the water environment.

So, therefore it wants to have a non aqueous system for example organic solvents, so therefore if you have some organic pollutant present in the system so these particular tail group of the surfactant will love to have that environment of organic pollutants or the organic phase.

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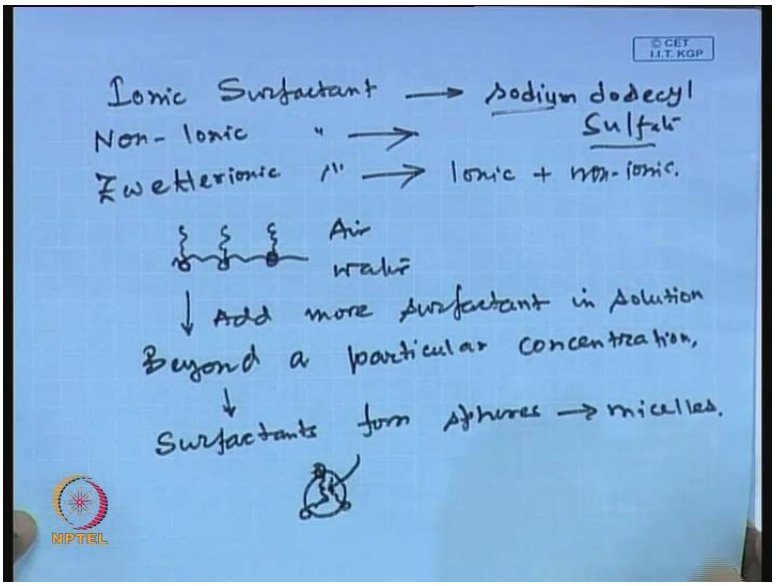

Now, there are several types of surfactants that we will again go into details of the this, one is the ionic surfactant, another is the non ionic surfactants, zwetterinic surfactant.

Now, these ionic surfactants they have one ionic group present like for example sodium dodecyl sulphate, these sodium dodecyl sulphate will be having n a plus and s o 4 minus in its structure, therefore these impairs an ionic characteristic you can have the non ionic surfactants like polyether oxygen you can have the so zwitterionic surfactants they have the both ionic and non ionic characteristic.

Now, there are several properties of the surfactants which impart the you know which leads to the separation of solutes, for example if you have a if you keep on if you have a water and if you have a bucket of water let us say and if you put some surfactants then the surfactant head groups will be water loving the hydrophilic groups, and the surfactant tail groups will be hydrophobic they do not like water, so they will be aligned at the surface pointing to the head towards the solution, and pointing the tail away from the solution, and it will be pointing to the air. Suppose air and water so therefore surfactant monomers or surfactant molecules will be aligned themselves across the air water interface pointing their hydrophilic head towards the water, and their hydrophobic tail towards the air.

Now, if you keep on increasing the concentration surfactants at more surfactants into solutions in solution then what will happen this surface will be no longer infested by the surfactant molecules what this where this surfactant monomers will do they will form globules to achieve the minimum energy configuration, that is thermodynamically favourable and stable, what is that configuration it is a solid sphere, it is not a solid sphere, so a if you keep on adding surfactant solution beyond a particular concentration, beyond a particular concentration these surfactants form a globule or a sphere surfactants form spheres known as micelles. So, in micelles any anyway we will be going these things in detail whenever we are talking about micellar enhanced ultra filtration, these I will just I am just mentioning the property of the surfactants which will be causing or leading to the separation of the solutes, these micelles will be having the hydrophilic head towards facing towards the aqueous environment and hydrophobic hydrophobic tail insult.

So, if you have a solute that will be present that is organic phase that will be immediately going into the hydrophobic environment, it will be immediately solubilised into the hydrophobic environment, now these micelles are being larger in size they will be trapping the organics and they can be separated by the and by a tipic suitable selected

membrane, and one can remove the organic pollutants using micelles against ultra filtration, and this process is known as M e u f or micelle micellar enhanced ultra filtration.

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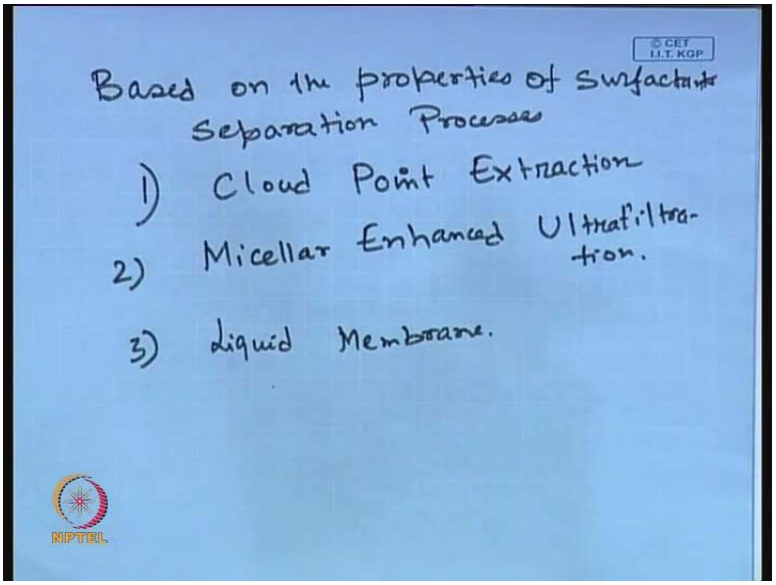

So depending on the properties of the surfactants typically these surfactant based separation processes can broadly be categorised into 3 categories, based on the properties of surfactants this separation processes are categorised into 3 classes, one is cloud point extraction, secondly micellar enhanced ultra filtration, third one is liquid membrane. In fact what we will be doing we will be going one after another in this sequence and whenever we discuss a particular separation system we will discuss about the more detail mechanisms or phenomena or the fundamentals involved in all these processes, and finally our aim is to find out our aim is to get an idea how the designing of such systems can be done commercially in an in a commercial scale, as far as from the chemical engineer point of view.

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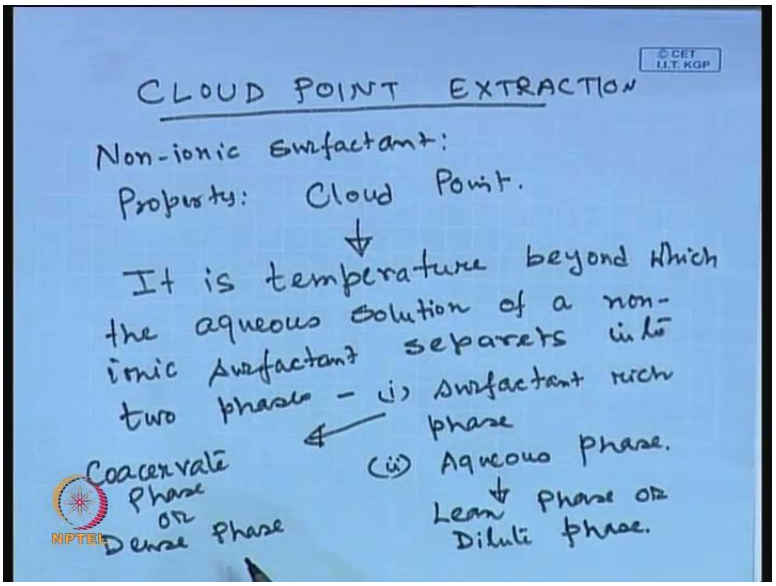

So, the first separation process that will be talking about is the cloud point extraction, this is another property of the surfactants of the non ionic surfactants these non ionic surfactants has a typical property this is known as the cloud point. What is a cloud point? It is a when you when you increase the temperature of aqua solution of an non ionic surfactants all the surfactants are basically surface active agents they are soluble in water aqua solution.

Now, if you have a an aqueous solution of non ionic surfactant and if you keep on increasing the concentration of increasing the temperature of the system, then beyond a particular temperature there occurs a face separation. What is that face separation? The surfactant molecules will all of the surfactant molecules will combine into one phase it is a thick phase and the other phase is basically an aqueous solution. So, you can if you look into the system you can clearly visibly you can distinguish that you will be having a lean phase that is quite you know density will be less so it will be on the top and the bottom phase will be (( )) one where all the surfactant molecules have come up, and there is a particular critical temperature beyond which it occurs that particular temperature is known as the cloud point temperature of the non ionic surfactants.

So, what is the definition of the cloud point? It is temperature beyond which the aqueous solution of a non ionic surfactant separates into two phases, one is surfactant rich phase, another is surfactant lean phase or the aqueous phase, this particular temperature is

known as the cloud point corresponding to that particular non ionic surfactant. So, every non ionic surfactant will be having its own characteristic cloud point temperature.

Now, there are some names of these two phases this surfactant rich phase is known as coacervate phase or the dense phase or dense phase, and aqueous phase is known as lean phase or a dilute phase, so the coacervate phase will be rich in surfactants so this coacervate phase is is also known as it is rich in surfactants.

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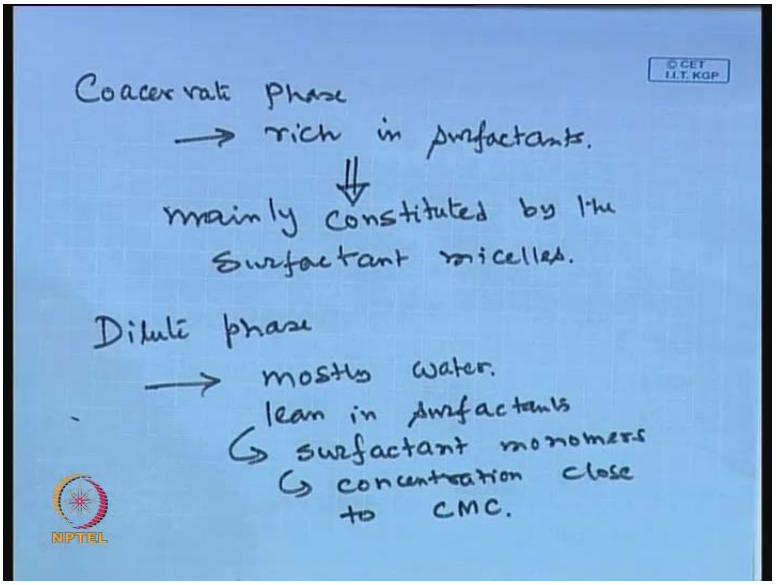

And it is mainly constituted by the surfactant micelles, because most of the non ionic surfactants we when you talk about the micellar enhanced ultra filtration, we talk about the micellar concentration, mostly these non ionic surfactants will be having very low critical micellar concentration.

So, if you have a concentration slightly above that forming the micelles, now if we increase the temperature of the surfactant solutions these micelles will be separated and going into the coacervate phase, so mostly this coacervate phase will be rich in surfactants and almost all the surfactant micelles will be present in the coacervate phase, so it is mainly constituted by the micelle by the surfactant micelles, and the lean phase or the dilute phase or the aqueous phase this is mostly water there are surfactant monomers are present lean in surfactants and you will be having surfactant monomers will concentration what is the concentration of that at a concentration level close to C M C or critical micellar concentration.

Now, this so basically they will be having separate surfactant you know monomers and their concentration will be near to the critical micellar concentration, and in the coacervate all the micellar surfactant micelles will be agglomerated and they will form a separate dense phase, so if you have a phase separate of funnel the lower phase will be the coacervate phase and the top phase will be the dilute aqueous phase.

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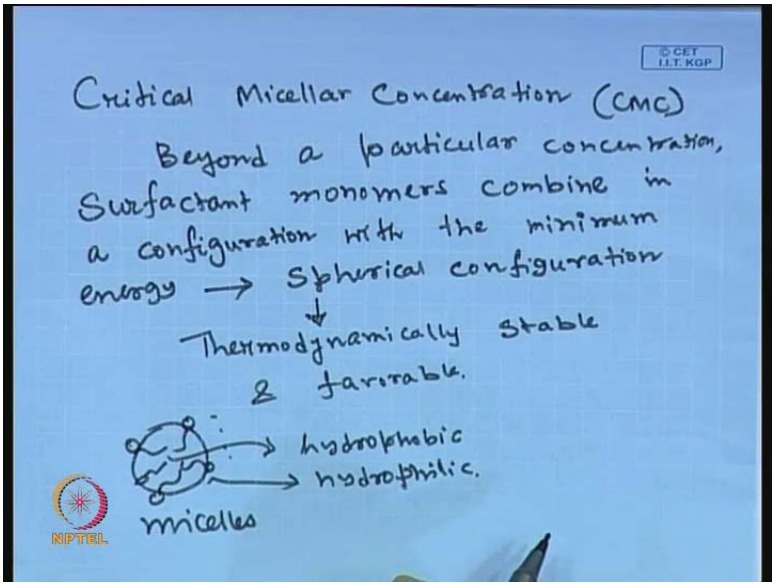

Now, let us come to the definition of the critical micellar concentration, concentration or it is also abbreviated as C M C now when you keep on increasing as I said earlier that when you have surfactant molecule at a surfactant at lower concentration the monomers will be separated each of them will be separated, now if you have let us say a bucket of water if you add a surfactant then the surfactant monomers will be aligned near the surface, and the alignment will be such that the hydrophilic head will be pointing towards the aqua space or the water side because it is water loving, and the hydrophobic hydrophobic tail will be pointing towards the air.

So, now if you keep on increasing the surfactant concentration beyond a particular point this surfactants will be no longer staying in the inter phase they will form globules to attain the minimum thermodynamic configuration with the minimum energy which is thermodynamically favourable and stable that a that configuration will be a spherical configuration, this sphere is known as the micelle.

So, beyond so what is the definition of critical micellar concentration, beyond a particular concentration surfactant monomers combine in a configuration with the lowest energy with the minimum energy and this configuration is nothing but a sphere a spherical configuration that is thermodynamically stable and favourable of course.

Now, these globules are known as the micelles. These micelles the hydrophilic head will be pointing towards the aqua surface aqua space, and the hydrophobic tail will be pointing towards the inside the towards the core of the micelle, so core of the micellar within the micelle the environment is hydrophobic, and outside it is hydrophilic.

Now, these so this is these are the basically called micelles, and this definition of critical micellar concentration that beyond a particular concentration it forms the globules. Now, these micelles will be of the non ionic surfactants will be coming to the coacervate phase when there is a phase separate when there is a what is that temperature of the particular solution goes beyond a cloud point temperature.

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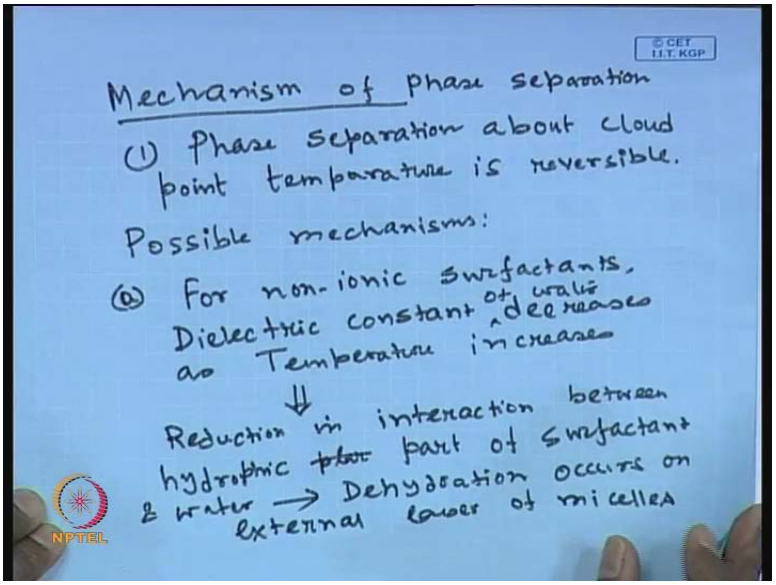

Now, let us look into the mechanism of phase separation, how the two phases will separate this phase change about C p t is reversible, that means first characteristic is phase separation about the cloud point temperature is reversible, that means if you increase if you go beyond a particular temperature cloud point temperature the phases will separate, the micellar rich phase and the aqueous phase, if you lower down the temperature below the cloud point temperature again the two phases will mix up and you

will be having the phase as earlier, so it is a reversible phenomena and the possible mechanisms are number one for non-ionic surfactants dielectric constant of water decreases as temperature increases, dielectric constant decreases as the constant of water decreases as temperature increases.

What does it do these results in to this reduces the reduction in interaction between the hydrophilic part of surfactant and water. What does that mean? It means that there is a dehydration occurs at the external layer of the micelle because at outer surface there is a hydrophilic layer so if the if it does not like the water environment then it there occurs dehydration. So, water will be repelled from the outer surface so it results into dehydration occurs on external layer of micelles. The second mechanism

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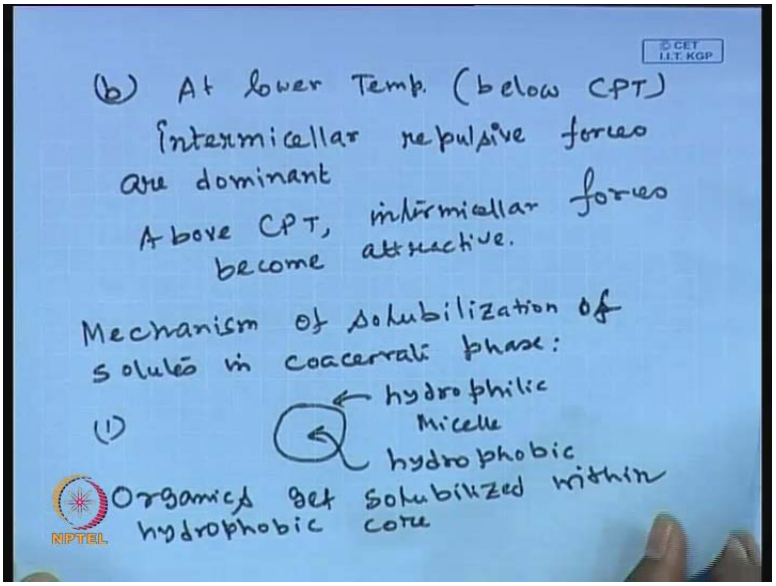

so when it therefore all every micelles will have will be having a tendency to repel water out of it, though the second possible mechanism is that at lower temperature at lower temperature means below cloud point temperature below cloud point temperature inter micellar forces are dominant and they are repulsive forces, inter micellar repulsive forces are dominant, but when the cloud point is approached or above cloud point temperature they become attractive.

So, what is the net result? Net result is the micelles would like to repel water and they will form a coercive forces among itself so the phase separation occurs. Now, what is the so that is the mechanism of phase separation, and what is the mechanism of

solubilisation of solutes in coacervate phase let us look into that mechanism of solubilisation of solutes in coacervate phase the first mechanism is that if you look into the structure of micelle, the outer phase is water loving or hydrophilic, the interior of the micelle is hydrophobic in the aqua solution.

So, if you have some organic solutes present in your system for example phenol, for example you know aniline, or some dyers or some kind of organic like P c b or things like that then these hydrophobic organic solutes will be immediately solubilised within the hydrophobic core of the micelle, so and this transfer solubilisation is almost instantaneous there is and that time gap will be in the order of nano second, so whenever you will be having solutes organic solutes present in the system they will be immediately solubilised in the hydrophobic core of the micelles. So, organics get solubilised within hydrophobic core of micelles, now once that is done then if you have a let us say some concentration of the organic solutes they will be completely solubilised within the hydrophobic core.

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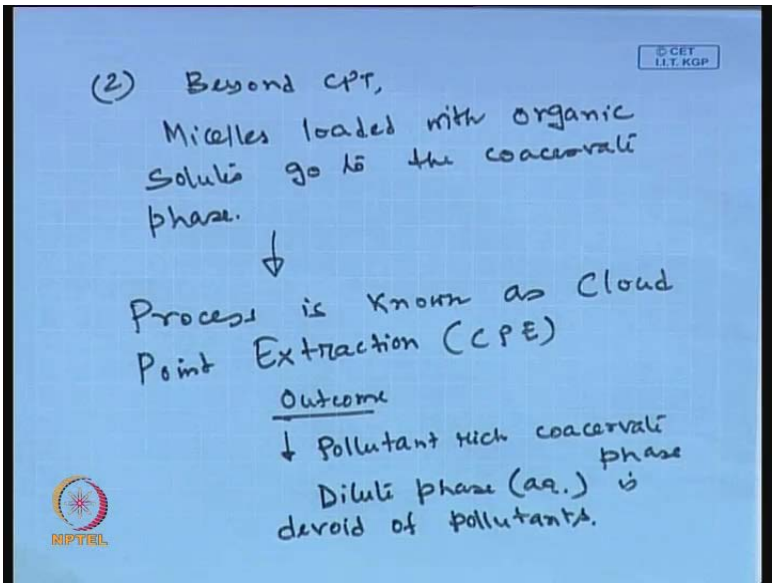

Now, next step what is what you have to do you increase the temperature of the solution, now if you go beyond cloud point temperature this micelles which are loaded with the organic solutes they will be separated into the coacervate phase, there may phase separation occurs and these micelles loaded with the organic pollutants will go into the coacervate phase, micelles loaded with organic solutes go to the coacervate phase.

So, you will be having a clear almost a clear solution in the in the aqua space, that is devoid of the organic pollutants, so thus the you know solubilisation of the solutes in the and then the you know cleaning of the separation of the organic pollutants will occur in the cloud point extraction and these whole process is known as the cloud point extraction. process is known as cloud point extraction or C P E. And what is the net results of this the outcome is if you having a solute rich coacervate phase pollutant rich coacervate phase and at the same time you will be having an aqueous phase which is almost the almost devoid of the pollutants, dilute phase this is nothing but the aqueous phase which is devoid of organic pollutants.

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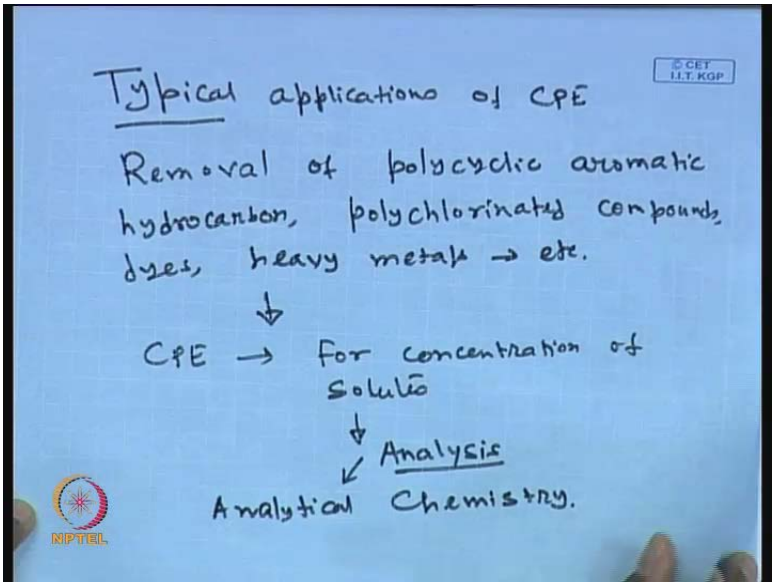

So, that is the principle of cloud point extraction and then let us look into some of the applications of typical applications of cloud point extractions, remove of removal of P a h these are this is known as the polycyclic aromatic hydrocarbon, these P a h are abundantly available from in the in the aqua space or in the water near the refineries, this P a h are the carcinogenic they are cancer causing the components so removal of P s e's P a h removal of polycyclic aromatic hydrocarbon, poly chlorinated compounds, dyes, heavy metals etcetera, so these are all cancer causing and components present in the aqua system in depending on their source of the aqua of the water that you are going to have in different places different locations.

Now, cloud point extractions can be utilised to remove all these pollutants selectively from the aqua stream, so in fact what it does in the since the coacervate phase will be a concentrated phase its volume will be much less so in a small volume one can capture or trap all the pollutants in one particular phase, so therefore the concentration since the volume is much less in the coacervate phase the concentration of the pollutants will be very high in that particular phase, and why is that what does that mean that means it will be a concentrated phase, so one can use this thing one can use cloud point extraction for concentration of solutes, so this has a tremendous implication in the analysis.

So, what is the implication? Implication is you if you have a dilute stream of a of dilute solution of a particular pollutant then it is very difficult to analyze it to measure it is concentration quantitatively using a you know using an instrument, for example u v spectro photo meter, or h P l say whatever, but if you can increase the concentration it will be much easier to detect it via an instrument.

So, cloud point extraction is often used as an analytical tool to increase the concentration of such a pollutant so there is concentration will be increased and then it will be detected in an instrument, so this is a very good useful method for analyst analytical chemistry, this is an useful method for as far as the pollution control is concerned this is an useful method as far as the analytical chemistry is concerned.

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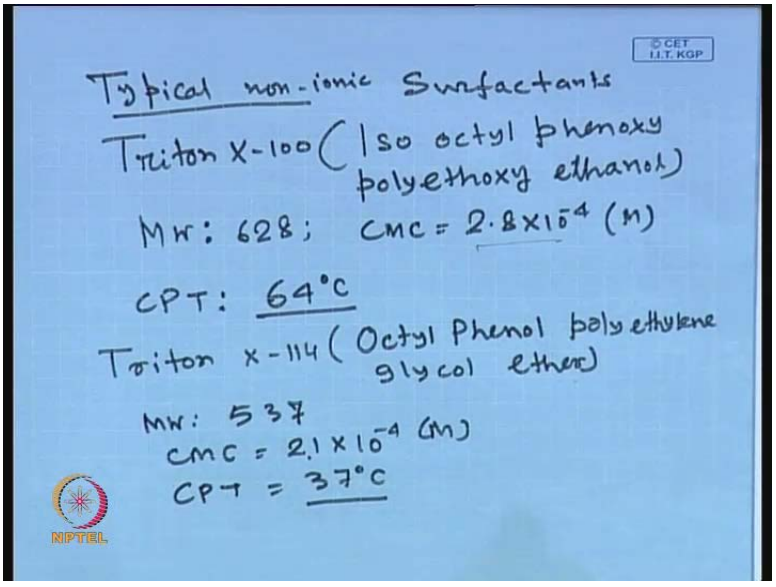

Now, let us look into some of the typical non ionic surfactants, the first and will study it non ionic surfactant is known as triton x 100. Its name is its chemical name is iso octyl phenoxy, polyethoxy ethanol, it has a typical molecular weight of 628, it has a C M C which will be extremely small C M C will be 2.8 into 10 to the power minus 4 molar, that means if you add the triton x surfactant in the aqua solution such that its concentration just goes beyond these value 2.8 into minus (( )) you see it is so small, it is in the order of 10 to the power minus 4 molar, if you it is increase a several drops of you know this particular surfactant in the aqua solution if its concentration goes beyond its particular value they form (( )) spherical surfactant micelles will be formed, and the cloud point temperature for this particular surfactant is 64 degree centigrade.

The next common non ionic surfactant is triton x 114, its name is octyl phenol polyethylene glycol ether, it is a molecular weight of 537 it has a C M C in the same order of magnitude of that of triton x 100 is 2.1 into 10 to the power minus 4 molar, and it has a cloud point temperature 37 degree centigrade. So, that drastic difference between the two surfactant is that in triton x 100 it has a cloud point temperature quite high 64 degree centigrade. On the other hand in triton x 114 it has a cloud point temperature almost half of it, it is very close to 40 degree centigrade its 37 degree centigrade.

So therefore, if you would like to have a cloud point extraction using triton x 100 we have to go for higher temperature, that means your solution temperature must be around 64 degree centigrade, so therefore you must be standing much energy much thermal energy to achieve that separation, because you are operating temperature must be around 70 degree centigrade or 80 degree centigrade so that it goes beyond the cloud point temperature. On the other hand if you go for the cloud point extraction using triton x 114 you can operate at a very low temperature around 37 degree centigrade 40 degree centigrade, but on the other hand triton x 114 is much costlier compared to triton x 100.

So, one has to have a tradeoff between the cost, and you know cost of the raw materials and the cost that is incurred into the utility like the energy that you are going to put into the system.

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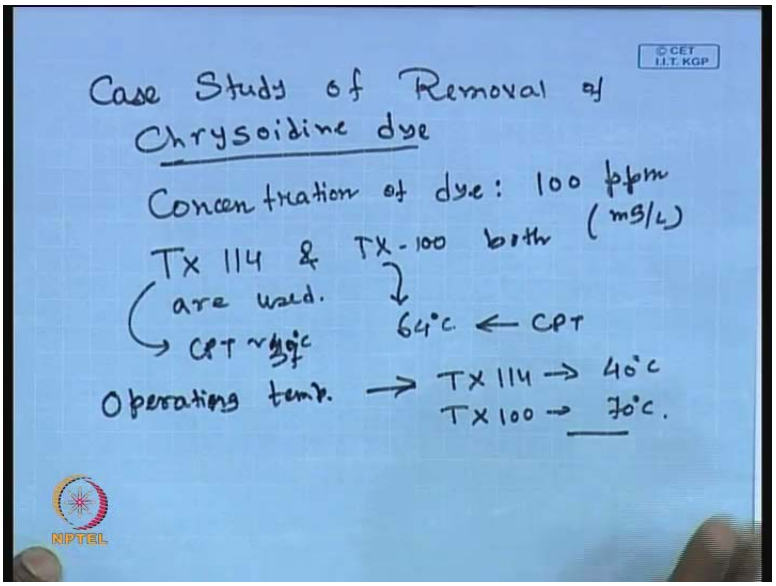

Now, what we do next I will present a case study of removal of particular dye using cloud point extraction, I present a case study of removal of a dye it is know as the chrysoidine dye for a using cloud point extraction, and both a typical concentration of 100 P p m of a dye is selected, that we have selected is around 100 P p m that means P p m is milligram per liter, and both triton x 100 and triton x t x 114 I used, t x 114 and t x 100 both are used.

Now, cloud point of temperature of t x 114 that we have seen is around 40 degree centigrade and this will be this it is 37 degree centigrade and this will be for 64 centigrade, so one can have the operating temperature slightly above that, this is the cloud point temperature so operating temperature will be higher than this so minimum operating conduct temperature that one should have will be for t x one for will be around 40 degree centigrade, and for t x 100 it can be around 70 degree centigrade.

Now, the temperature obviously is lower for t x 114 but on the other hand as I mentioned earlier it will be costlier.

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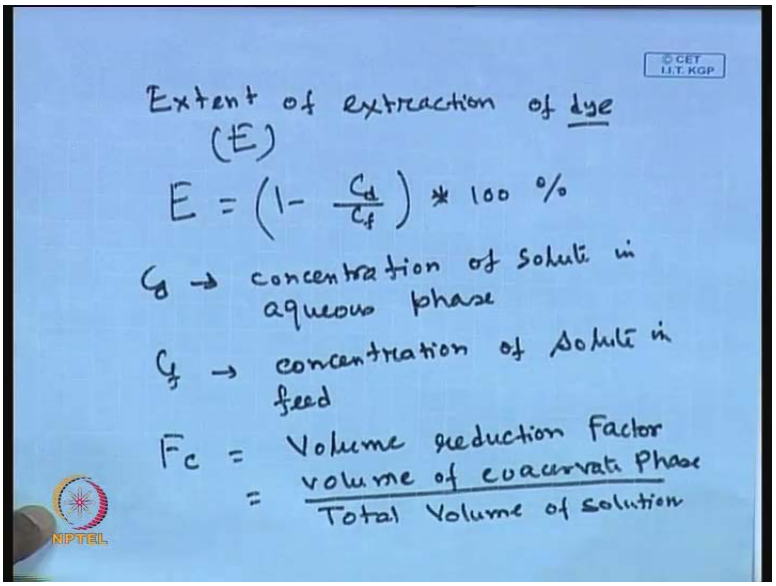

Now, we can define the extraction of dye the separation must be quantified right how much separation has been as been achieved that must be quantified so it is known as the extent of extraction, for this particular case it is dye but it will may be any other solute so these extent or extraction is defined by the symbol E, and it is defined as 1 minus C d by C f multiplied by 100 percent, so it is expressed in percentage and C d is concentration of solute in aqua space and C f is the concentration of solute in feed, and this solute in this particular case is dye.

Now, also during cloud point extraction as we have mentioned the volume of the coacervate phase will be much lower compact to the initial volume because a if you observe the mechanism of cloud point extraction is that removal or know the repulsion of the water or from the outside layer of the ethoxy group of the my cells. So, it will be dehydrated, so most of the micelles will be coming in coacervate phase reducing its volume drastically, so volume will be reduced compared to the feed volume in that coacervate phase.

So, this is known as this is defined into the volume reduction factor, and this volume reduction factor is defined as volume of the coacervate phase, divided by total volume of solution.

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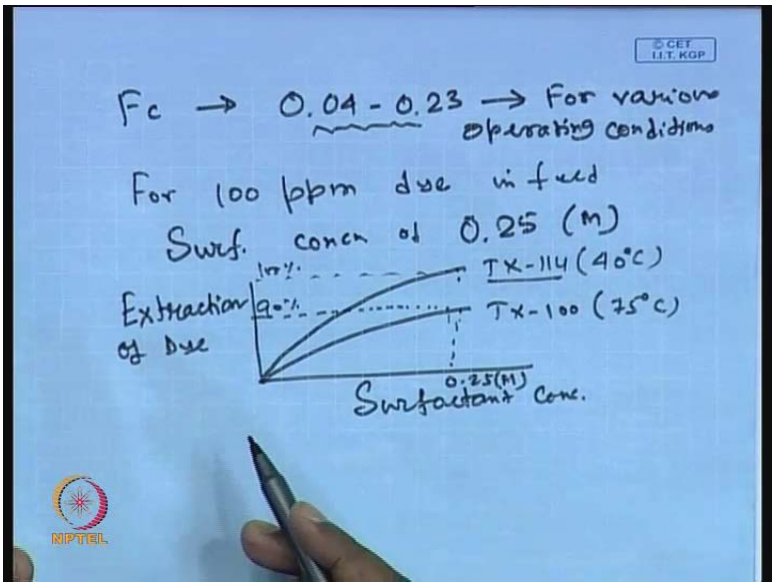

So, that is a defined a definition of volume reduction factor, and typically the value of f c will be in the range of 0.04 to 0.23 for various operating conditions. I intentionally gave these values because you can understand what is the actual volume reduction will occur, the volume reduction will be not in the order of 2 times 3 times not by 50 percent, not by 70 percent it will be extremely small, so volume reduction will be to the tune of 0.04, 0.23, that means 4 percent to 20 percent, that will be the order of volume reduction we are talking about in this particular case.

Now, we can give an idea how much extraction one can have if you have a surfactant concentration for 100 P p m, for 100 P p m dye in feed and if you select a surfactant concentration of 0.25 molar, then one can remove 95 percent of dye using t x 114, t x 100 and using t x 114 you can extract in the tune of about 100 percent.

So, we so if you plot the extraction of dye in percentage as a function of surfactant concentration, as you increase the surfactant concentration the extraction will be more, so you are going to get a curve something like this, the efficiency of t x 114 is much higher, so the upper end temper is 40 degree and t x 100 the operating temperature is 75 degree centigrade, and one can get and extraction efficiency that will be quite high these at 0.25 molar.

So, it will be closed to at 0.25 molar one can get around 100 percent extracting if you use t x 114 and you will be getting around 95 percent this will be around 100 percent, and

this will be around 90 percent extraction using t x 100. Anyhow we will continue we will stop here we will this discussion in the next class.

Thank you very much