Novel Separation Processes
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Lecture No. # 31
External field induced
Micellar Enhanced Ultrafiltration

Good morning every one. So, will be talking about a discussing about the surfacing material separation processes and in the last class so there are costly (( )) there are the surfactant separation process can be categorised in to three processes. One is cloud point extraction that we have discussed in detail in the last two classes. And micellar enhanced ultra filtration and liquid membrane. In last class whatever, we did will talked about a detail analysis of a cloud point extraction and will have seen the design of the cloud point extracted and we have seen particular example how to design a cloud point extractor.

Now, we so we solve the problem this problem was based on let us given the extraction of particular dye using the cloud point method using an non ionic surfactant. Now, we have seen in the given a particular concentration of the dye and two what exchange of to you (()) suppose, that concentration is known as then what is the surfactant required to separate to effect, that kind of separation to a particular extend. Now, in today class will first solve a problem another problem on cloud point extracted and then will move on to the next topic that is micellar enhanced ultra filtration.

So, in today's problem again is a problem of dye separation because parameter of the dye with the surfactant is you with non ionic surfactant is known to us so, will be again talking about the dye separation problem. But in this case the surfactant amount is given and the feed concentration is given we have find out what will be the dilute concentration whatever the is the final concentration of the dye in the dilute phase that will give you the extend of separation.

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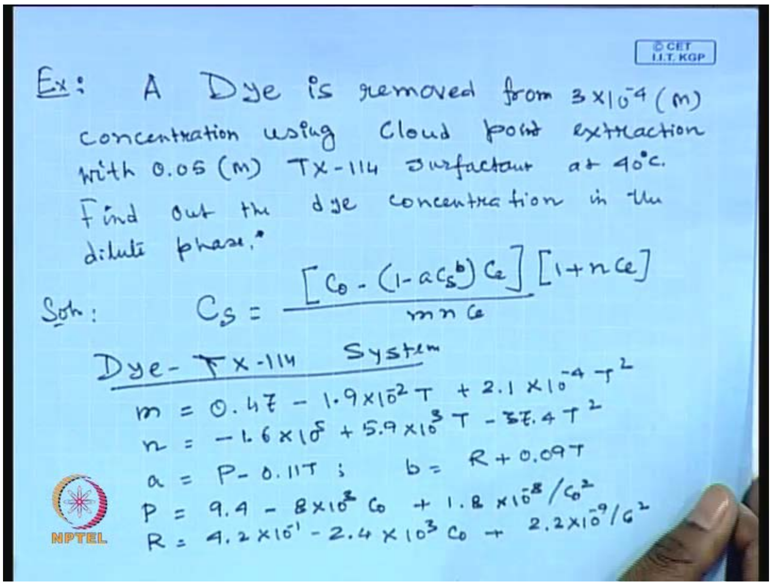

Ex: A Dye is removed from 3×10^{-4} (M) concentration using Cloud point extraction with 0.05 (M) TX-114 surfactant at 40°C. Find out the dye concentration in the dilute phase.

Soln:

$$C_S = \frac{[C_0 - (1 - aC_S^b)C_e][1 + nC_e]}{mnC_e}$$

Dye-TX-114 System

$m = 0.47 - 1.9 \times 10^{-2} T + 2.1 \times 10^{-4} T^2$

$n = -1.6 \times 10^5 + 5.9 \times 10^3 T - 37.4 T^2$

$a = P - 0.11T$; $b = R + 0.09T$

$P = 9.4 - 8 \times 10^{2} C_0 + 1.8 \times 10^{-8} / C_0^2$

$R = 4.2 \times 10^{-1} - 2.4 \times 10^3 C_0 + 2.2 \times 10^{-9} / C_0^2$

So, this problem the this example, talks about a dye is removed from 3 into 10 to the power minus 4 molar concentration using cloud conduct extraction with 0.05 molar T x 114 surfactant at 40 degree centigrade. Operating temperature is 40 degree centigrade cloud point of T x 114 are (()) 37 centigrade. So, we have to find out the dilute phase concentration or the dye concentration in the dilute phase. This a reverse problem of whatever, you have solved in the last class. So, let us look in the solution and let us writet down the design equation for the cloud point extraction. The concentration of surfactant required is given as C g o minus 1 minus a C s to the power b times C e 1 plus n times C e divided by m n C e.

This are design equation for the surfactant concentration given a feed concentration of dye that is C naught and dilute concentration dye concentration in the dilute phase an aqueous there is C. And a b exedra of the isotherm a minus exedra the isotherm constant and a b of the properties are the are the constant the where create the various properties of the surfactant system. For dye and T x 114 system the following parameters are known to us. The m value is given this is the function of temperature these are the absorption isotherm parameter minus 1.9 into 10 to the power of minus 2 T plus 2.1 into 10 to the power of minus 4 T square, n is equal to 1.6 into 10 to the power of 5 plus 5.9 into 10 to the power of T minus 37.4 T square.

The parameter a is given as P minus 0.1 1 T b is given as R plus 0.0 9 T and the value of parameters P and R given as the concentrate as the function of feed concentration of the dye. P is given as 9 0.4 minus 8 in to 10 to the power 3 C not plus 1.8 in to 10 to the power of minus 8 divided by C not square. And the parameter R is given as 4 0.2 into 10 to the power of minus 1 minus 2 0.4 into 10 to the power 3 C not plus 2 0.2 into 10 to the power of minus 9 C not square. So, the this parameters a and b as the function of temperature the parameters, P and R are the function of feed concentration of the dye they were given they where mean for the dye T x 114 system now main this relation.

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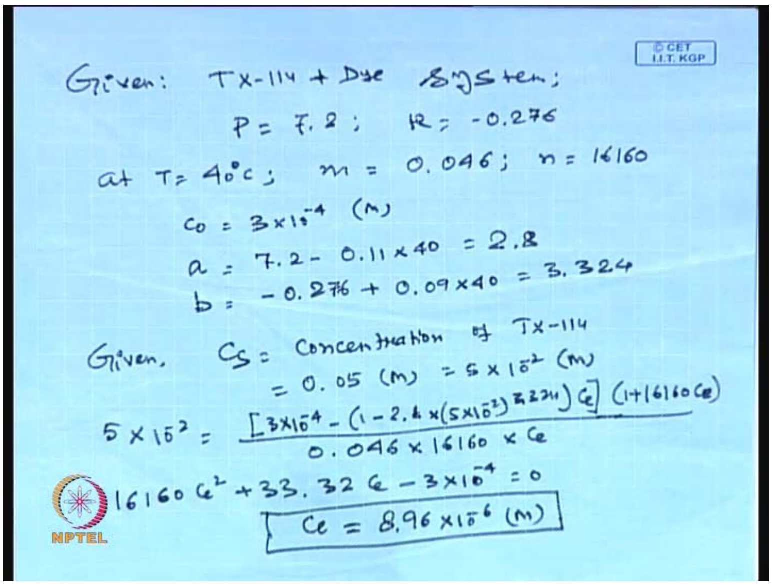

Given: TX-114 + Dye System;

$P = 7.2$; $R = -0.276$

at $T = 40^\circ C$; $m = 0.046$; $n = 16160$

$C_0 = 3\times10^{-4}$ (M)

$a = 7.2 - 0.11\times40 = 2.8$

$b = -0.276 + 0.09\times40 = 3.324$

Given, C_S = Concentration of TX-114

$= 0.05$ (M) $= 5\times10^{-2}$ (M)

$$5\times10^{-2} = \frac{\left[3\times10^{-4} - \left(1-2.4\times(5\times10^{-2})^{2.234}\right)C_e\right](1+16160\,C_e)}{0.046\times16160\times C_e}$$

$$16160\,C_e^2 + 33.32\,C_e - 3\times10^{-4} = 0$$

$$\boxed{C_e = 8.96\times10^{-6}\ (M)}$$

Now, let us proceed for the solution given that and it is given the for this system T x 114 and dye system. The value of P can be can be can be evaluated you put the value of C not as 3 into 10 to the power of minus 5 molar and in the variation the P and R given as P transfer to be 7 0.2 and R transfer to be minus 2.0 0.7 6. Then at temperature 40 degree centigrade the value of m and n are given the expressions are given so, you can evaluate that m transfer to be 0.0 4 6 and n transfer to be 1 6 1 6 0. So, once you know and also know the value of C not that is 3 in to 10 to the power of minus 4 molar. So, you can evaluate the order parameters and once you know the temperature T you know the value of P you can evaluate the value of a this 7 2 minus 0.1 1 into 40 transfer to be 2.8.

Just put the value in the correlation b transfer to be minus 2 0.7 is 0.2 seen 6 plus 0.0 9 into 40 it is equal to 3 0.3 2 4. Now, it is given that the concentration of surfactant in this particular problem is presented as 0.0 5 molar. C s is concentration of T x 1 1 4 it is 0.0 5 molar so, 5 into 10 to the power of minus 2 molar. For put this value if to the design equation that this is an equation means in to this equation and you can what will be getting is this, 5 in to 10 to the power of minus 2 is equal to 3 into 10 to the power of 4 minus 1 minus 2.8 into 5 into 10 to the power of minus 2 rest to the power 3 0.3 2 4 bracketing multiplied by C e there bracket close is 1 plus 1 6 1 6 0 C e.

So, this divided by 0.0 4 6 into 1 6 1 6 0 in to C e. So, just simplify this z of equation is transfer to be 1 6 1 6 0 C e square plus 33.32 will b e minus 3 into 10 to the power of minus 4 is equal to 0. So, that gives you a quadratic in terms of C and if you solve this expression you will be by using the you know see quadratic equation solute (()) of the quadratic equation minus b plus minus plus minus will be 500 400 that divided by (()) 2 a. So, that will that give the 8 point 9 6 in to 10 to the power of minus 6 smaller. So, this is the concentration that we are going to get from a feed concentration the dye of from 3 in to 10 to the power of minus 5 molar 2 8.9 6 into 10 to the power of minus 6 molar.

So, you can will be able to reduce the concentration of dye the using the cloud point extraction from an order of magnitude of 10 to the power of minus 4 to 10 to the power of minus 6. So, the extend of the extraction or removal will be more than 9 9 percent. So, this example, illustrate to how to use how to design a cloud point extracted so there are two types of problem one can phase, if you like to bring down the concentration of pollutant from a particular level down to the particular level. Then what is the concentration surfactant will be electro required? Or if you have the if you select the concentration of surfactant, there is the second by the reverse process a problem for solved in to today class.

If you have if you know the surfactant of the concentration then what will be the extend of separation? That you can get what is the concentration of the pollutant in the dilute phase. So, you then you will placed on the topic of cloud conduct extraction that will move on to the next topic of surfactant enhanced separation processes.

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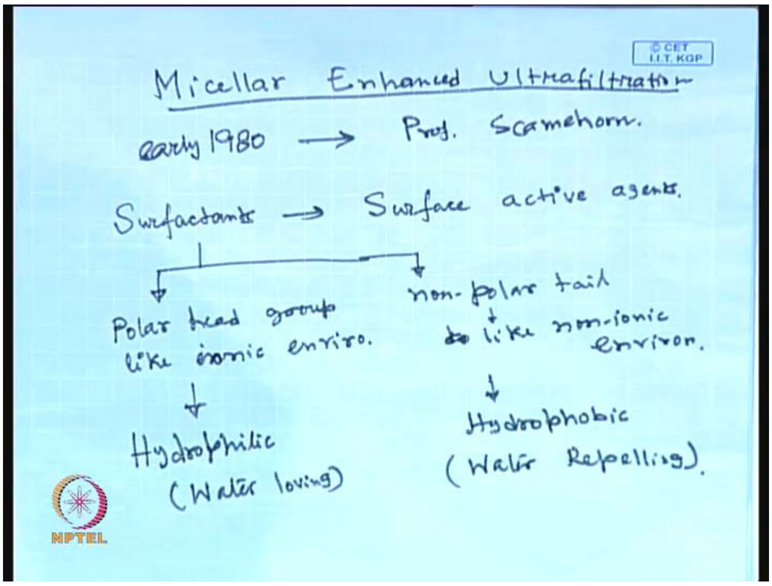

Micellar Enhanced Ultrafiltration

early 1980 → Prof. Scamehorn.

Surfactants → Surface active agents.

Polar head group
like ionic enviro.
↓
Hydrophilic
(Water loving)

non-polar tail
↓
~~do~~ like non-ionic environ.
↓
Hydrophobic
(Water Repelling).

That is micellar enhanced ultra filtration. This is a resent topic and this topics for the developed the first paper there, appeared on the topic we can surface in the year of early 1980s. And professor scamehorn is bilinear on micellar enhanced ultra filtration here develop the topic and the this particular technology. And this technology will be still under laboratory resize the (( )) scale and it is not you know you does not gone up to the you know commercialise are the point scale. The idea is you can use the surfactants in order to effect a good separation of a of organic or inorganic pollutants. Now, let us look into the sur surfactant so, the surfactants surfactant is nothing, but the surface active agents.

This surfactant of their they have the polar head group and non polar non head group there is the typical characteristic of the surfactant. Polar head group and non polar head group tail that means, polar head group means they laugh the aqueous solution they there are the of the like the ionic environment. Like ionic environment on the other hand the non polar tail they do not like the ionic environment. They like non ionic environment and the other hand you can say, that this polar head group hydrophilic water loving. Their hydrophilic and this non polar tails the hydrophobic water repelling this are the, typical characteristic of the surfactant in the last the last terminal is (( )) discussed about the cloud point extraction.

If you put surfactants in an electro solution this surfactant will be always, alien them surfactant molecules will alien themselves across the pure water interface. Pointing out the hydrophilic gel towards the here (( )) and hydrophilic head over (( )) by the water.

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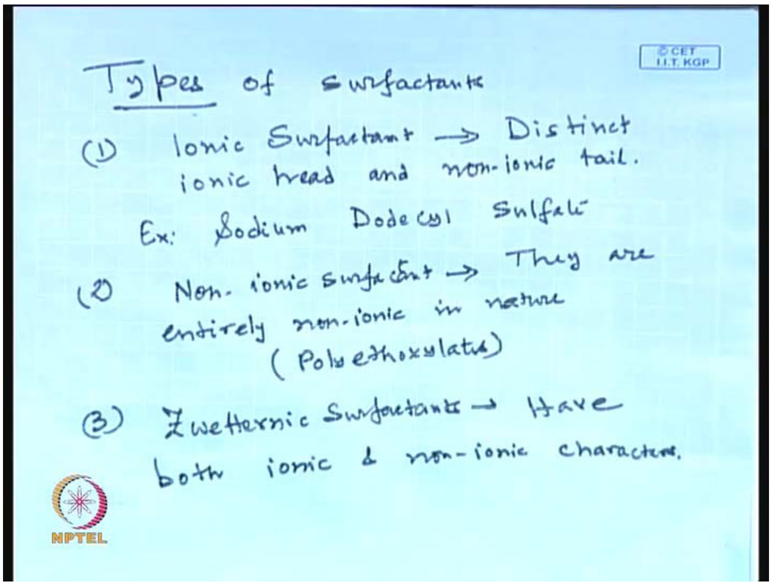

Types of surfactants

(1) Ionic Surfactant → Distinct ionic head and non-ionic tail.

Ex: Sodium Dodecyl Sulfate

(2) Non-ionic surfactant → They are entirely non-ionic in nature (Polyethoxylates)

(3) Zwetternic Surfactants → Have both ionic & non-ionic character.

Now, there are three types of surfactant generally, you can encountered. Types of surfactant, first one is ionic surfactant they have the for the distinct ionic head and non ionic tail and non ionic tail. The example is sodium, dodecyl, sulphate, cetyl, pyridinium chloride. Second one is non ionic surfactants, this non ionic surfactants they non ionic in nature they are entirely non ionic in nature that means the always hydrophobic nature. Example, poly ethoxylates in fact this are the this are the thermal of various of compound ethoxylate turbines (( )). Third one is zwetternic ion surfactants, they have both ionic and non ionic characteristic.

So, these are the various kinds of surfactants you will encounter, next you talk about the ionic surfactants only.

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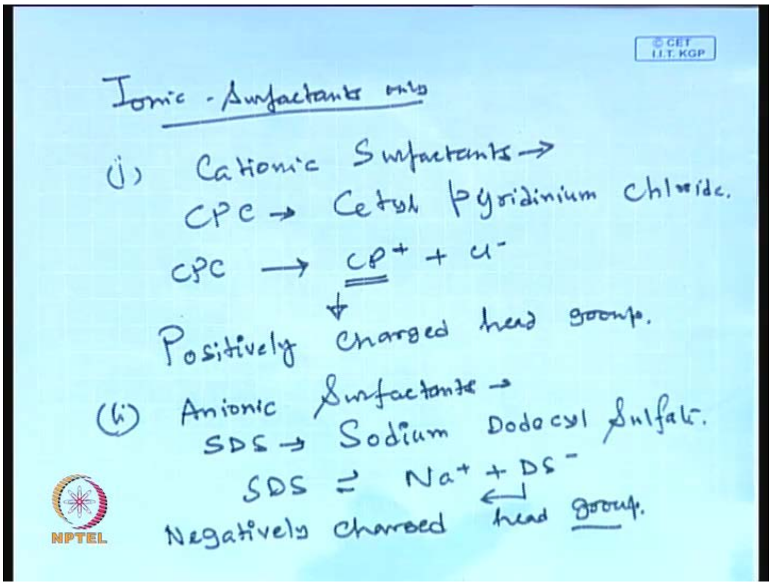

Ionic - Surfactants [illegible]

(i) Cationic Surfactants →

CPC → Cetyl pyridinium chloride.

$$CPC \longrightarrow \underline{\underline{CP^{+}}} + Cl^{-}$$

Positively charged head group.

(ii) Anionic Surfactants →

SDS → Sodium Dodecyl Sulfate.

$$SDS \rightleftharpoons Na^{+} + DS^{-}$$

Negatively charged head group.

If you remember that when it talked about the cloud conduct extraction with talked about the non ionic surfactant only cloud point extraction is the process. The cloud point basically, this thickly feature by the non ionic surfactant, other hand in micellar enhanced ultra filtration you can use both ionic and one ionic surfactants to remove the poly tyles (( )). That if you like to remove the metal ions of the ionic pollutant, you must having ionic surfactant. Now, let us talk about the ionic surfactant first one is the first one is the cationic surfactants example is C P C, cetyl pyridinium chloride.

Now, these surfactants the basically, it will be having cetyl pyridinium with the chloride now, when you put in to the aqueous solution this chloride is come out in the solution. The heads head group of this in the of this surfactant will be positively charged, because there will (( )) go away so, head group will be positively charged. For C P C you know water it is basically become basically C p mi C p plus plus C l minus C l will go goes in to the solution, though surfactant will be having a positively charged head group. Now, second one is anionic surfactant that is S D S, S D S is sodium dodecyl sulphate.

In sodium dodecyl sulphate will be having SDS when it when it goes in to aqueous solution it beds in to 2 part, N a plus plus D S minus. So, since N a plus goes in to the solution the surfactant will be having a negative head group in to the in acquire solution. So, it has negative recharged head group therefore, you can have four surfactant so, is the depending on the situation you can I just selected cationic surfactant are you can you can select them and anionic surfactant depending are open here (( )) need. And what is that need how to select the surfactant that will go? Details in to the next few arrange? (( ))

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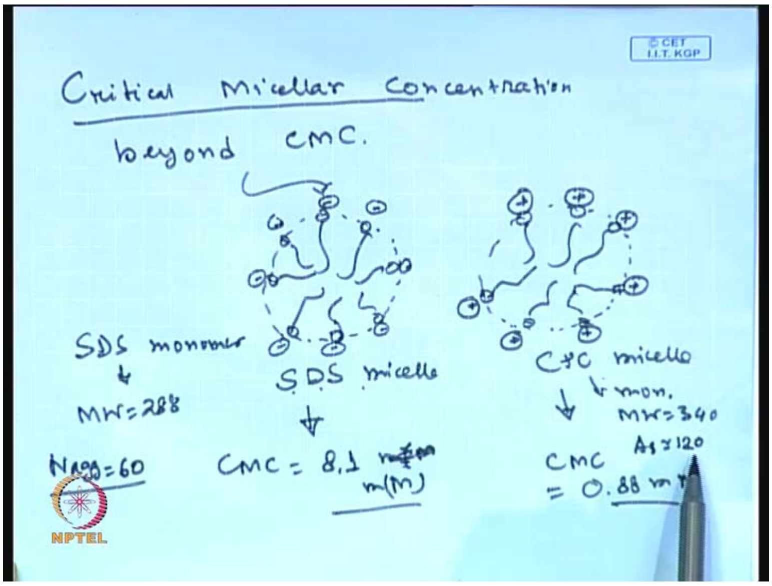

Then you talk about the concept of critilar micellar concentration although, we have already discuss the lot about the critical micellar concentration, regarding the discussion of cloud conduct extraction. I would like to go in to this discussion one again, I think said earlier that when you deserve the surfactants in to the aqueous solution? The surfactant molecules will align themselves, such that the hydrophilic head will be the order of polar head groups will be pointing close the aqueous solution hydrophobic head group will pointing towards the year. Now, if you keep on increasing the surfactant concentration beyond the particular concentration all this surfactant will not strict to this.

They will form to the bulk of solution having the thermal dynamically, favour configuration with the minimum possible energy. Why that for configuration? That will be a sphere. So, this surfactant will call will produce spherical agglomerates of this you know with the surfactant monomoise this agglomerates is called micellar. Now, the concentration beyond which this particular this separation of the configuration of the surfactant, will locker this concentration is known as the critical micells concentration. Therefore, beyond critical micells concentration the surfactant will form agglomerates or globules spherical globules called micells.

This for let say S D S micells and this is the C P C micells. So, hydrophilic head group will be pointing to us the water environment and hydrophilic head group will be point to us the pore of the sphere. So, these spheres will be having a polar outside surface and hydrophobic inside surface so, this core will be defiantly hydrophobic. That the nature of the hydrophilic outer surface will be depending on the kind of surfactant, that you have selecting. If you are selecting the sodium dodecy micelle the sodium dodecyl sur sodium dodecyl sulphate as the surfactant then sodium will goes in to the solution this outer surface will be negatively charged.

So, all these polar head groups will be having a negatively charged a negative charge residing over there. On the other hand if you talk about the if you select a cetyl pyridinium chloride micell surfactant this chloride going to the solution the out of group will be positively charge. So, this micelle will be have the positive positively charged out of surface on it. Now, typically what is the fundamental of N a (( )) that will be coming to the coming to electron, that before that we will like to find out. What is the typical concentration of you know? Typical values are the critical micellar concentration typically the value of C m c are pretty low for S D S, micells the value of C m c will be 8 0.1 milli molar.

On the other hand for C P C micelle the cri critical micelle concentration will 0.88 milli molar. So, these value are very low and you can have a if you increase the surfactant beyond the particular concentration you will be getting the formation of the micelle. And what will be the typical you know molecular of the monomer? The S D S monomer will be having a molecular weight typically 288 and C P C the monomer they will be having a molecular weight around 340. And in a typical S D S micelle the adumbration (( )) number the aggregation number will be roughly around 60. That means, will be having 6teen number of this surfactant monomers (( )) if the in a typical S D S micelle so, you can you can understand what is the molecular weight of the S D S micelle?

The molecular S D S micelle will be 60 in to 288 let us say around 300 it will be around 18,000. On the other hand the aggregation number of C P C will be around 120 around 100 around 120 so, will be having the molecular rate of this CPC micelle will be 120 into 340 it will be roughly around the you know 41,000 that so. Next let us so, we can know typically what is the you know mole typically molecular of this micelle, they will be ranging from around a 18,000 15,000 to around 15,000. Depending, on the kind of surfactant talking about and the the micellar formation and the aggregation number.

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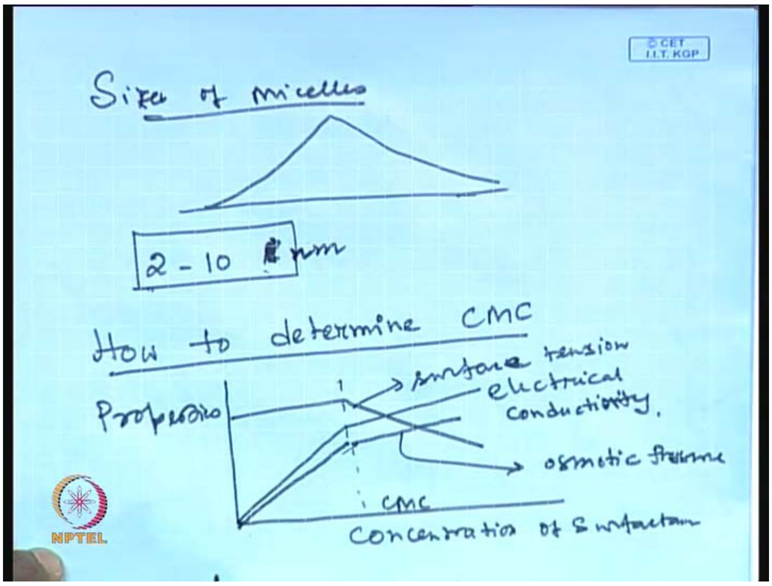

Size of micelles

2 - 10 nm

How to determine CMC

And what is the typical size of the micelle? This sizes of this micelle there is no clear cut size of the micelle that mean you own be having unique peak of the distribution. What will be getting? Will be getting a distribution of the size distribution of various micelle so, basically will be getting a distribution between say 2-10 Armstrong that will be the range of the various micelle and talking about the average size of the micelle. So, will be getting a distribution of the sizes and from that so, that that mean in ain a solution depending upon the concentration you can have surface micelle of lower molecular rate.

As well as, we can have the surfactant micelle of higher molecular rate so, there it will it will be a poly dispersed medium it will be a poly dispersed solution. The averaging you can average of the con the size and the average size will be varying from 2 -10 Armstrong depending on nature of the surfactant then the concentration of the surfactant we have talking about. Now, this surfactant micelle will be will be larger in size they can be separated by the ultra filtration membrane that is the idea. I think this will be nano metre 2-10 nanometres the they will be 2-10 nanometres so, it will be the range of 20-100 Armstrong it will be the range of the ultra filtration membrane.

So, ultra filtration membrane will be will remove this micelle. Now, next will be talk about how to determine the critical micellar concentration? That is very important, there are several properties those will change across the critical micellar concentration, if you track a particular property and if the and track it at the function of concentration, then will see that around see the slope of the curve will change. For example, if you plot property is verses concentration of concentration of surfactant, the surfactants will be more are less concentration then it will be reduce around C m c.

The conductivity the easiest one is electrical conductivity, I am talking about the C m c determination of non ionic surfactants. The if you increase the concentration of the surfactant the conductivity increases now, when it forms the micelle the micelle will be larger in size they are transport velocity will be reduced. Therefore, they will respond less conductivity they will result in less conductivity there is a change of slope of the conductive curve conductivity verses concentration curve around C m c. That is the easiest way to determined the C m c and I can tell you that this method is very very accurate with the conductivity metre that if generally, in a laboratory.

Next the osmotic pressure the osmotic pressure increases, sharply with concentration that beyond C m c the increase will be marginal. Because if you k now the concentrate the osmotic pressure will be pie is equal to R T C by it is inversely proportional to the molecular weight. So, when they are in monomer con condition so, their concentration there, the molecular will be less so, it will be function of linear function of concentration. So, it will increase rapidly almost linearly per minute from the micelle is molecular becomes more it becomes monomers so it will reduce. Therefore, it that will that will imply a change in slope of this curve, this is the osmotic pressure relationship.

So, there are and if you if you track down the surface tension the point around which the surface tension decreases, for ionic and non ionic surface tension does in matter that point on verses C m c on verse the surface tension decreases. So, if you track down some crucial properties of the solution you can under you can measure the value of critical micellar concentration.

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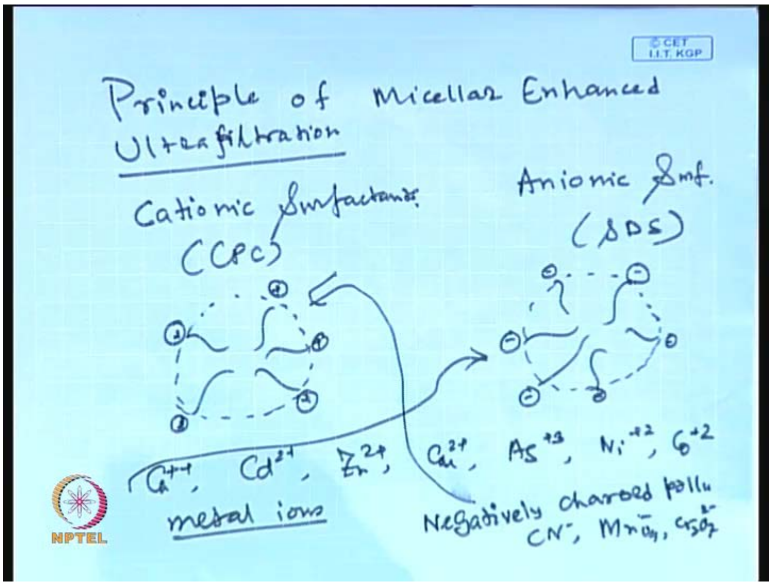

Principle of Micellar Enhanced Ultrafiltration

Cationic Surfactants (CPC)

Anionic Surf. (SDS)

Ca^{++}, Cd^{2+}, Zn^{2+}, Cu^{2+}, As^{+3}, Ni^{+2}, Co^{+2}

metal ions

Negatively charged pollu

CN^-, MnO_4^-, $Cr_2O_7^{2-}$

So, next we come to the principle of micellar enhanced ultrafiltration.

Now, let us talk about the formation of micelle onwards so, we have let say cationic surfactants we have anionic surfactants. Cationic surfactant is cetyl pyridinium chloride C P C and ionic surfactant a typical one which is most widely studies and common is a CPC and S D S and S D S is sodium dodecyl sulphate. So, will be having a micelle which will be positively charged in case of C P C and micelle which use (()) outer surface is negatively charged in case of SDS. Now, the formation of the micelle are dynamic in nature that means, monomers come and monomers go the they join the micelle and the immediately go away.

So, the concentration of the surfactant so, there will be so after permission of beyond C m c there will be two surfactant species present in the solution. What are this two? One is the surfactant monomers another will be a surfactant micells and this formation of the micelle formation is dynamic nature that means, at every instant of time some monomers will come and join the surfactant some will leaves. Therefore, they will be are equilibrium therefore, the concentration of the surfactant monomers in the solution free surfactant will be at the level of critical micellar concentration. So, their if you talk about the in a micellar solution what is the concentration of the free surfactant that will be critical micellar concentration always.

Now, if you have and inorganic pollutants for example, if you have the metal ion metal ion means, cadmium calcium plus plus cadmium zinc copper arsenic at then you know there are various metal ions where, nickel cobalt plus 2. If you have pollutants like these metal ions then they will be attached electro static attached from the outer surface of this micelle like simply electro static attraction attractive forces. If you have the anions negatively if you have negatively charge pollutant for example, cyanide permanganate dichromate.

Negatively charge pollutants for example, C n minus M n O 4 minus C r 2 4 7 minus 2 minus, they will be attracted they will be attached from the outer surface of this so of this, Actually, the metal ions will be removed by the S D S micelle anionic surfactant, because there will be negatively charged outer surface. So, if you have if like to remove the metal ions calcium cadmium zinc copper arsenic nickel cobalt then you have to use the sodium dodecyl sulphate micelle surfactant, which micelle will be having a negatively charged. So, this positively charged anions will be the will be directly attached by electro static attractive forces of the outer surface in this micelle.

If you have negatively charged pollutants for example, cyanide N m 4 minus C r 2 s minus they will be attached on the outer surface of that of cationic surfactant like cetyl pyridinium chloride micelle, because there will be positively charged outer surface. Therefore, what you have doing? You are basically; generating large number of micelle because the that if you increase the concentration does in the number of concentration micelle is increased. And therefore, will be having large number of surface area because the size is small they will be in the order of you know nanometre. So, we 2-10 nanometres so will be having a large surface area in a small volume therefore, and those points will be basically, the points of adsorption of the counter ions.

Now, if you have organic solvent organic pollutant for example, phenolic compounds like, metal actor (( )) phenol Para actro (( )) phenol catechol (( )) like there are so, many aniline benzene. Every refinery you can go around the refinery the water of the closed to the refinery location of the refinery it will be basically, pollutant by the organic pollutants like phenolic pollutants benzene aniline all this are cancellers. There are corrosion (( )) will be compound now, if you this pollutants are typically organic in nature their typically hydrophobic in nature. And when you put the surfactant micelle in the solution, these organic pollutants will be immediately solubilise within the hydrophobic pore of this micelle.

So, if you have ionic pollutants by selection of the suitable surfactant they will be attached and the outer surface of the surfactant. If you have organic pollutants they will be immediately solubilised within the hydrophobic core of the micelle. Now, after the solubilisation of the organics are the hydro statically attachment of the inorganic this micelle will be select increase in it size. And this micelle will be having larger in size they can be removed by the ultra filtration membrane or more open membrane. So, what is the advantage of going to get hearing micellar enhanced ultra filtration?

The first one is if you like to have a physical separation process that means, you are not going to use any chemical separation process. What is the difference between the two? In chemical separation process you are going to use some additives some chemicals it may be a poly electrolyte it may be a coagulant or confluent or some other chemical, which will be added to the system. And they will form agloramarate (( )) or they will form precipitate and you are separate them of micelle (( )) separation. On the other hand in physical separation process we are not going to use any external agent by using a physical barrier we are going to separate species. For example, membrane is nothing, but area it is like filtration unit it is filter common filter.

But if you like to separate out this ionic pollutants are let say let say organic pollutant for example, phenol aniline benzene, their very small in size. They are not polymerised they are not big big molecule they are not like big polymer they are not big size molecule like they are not pectins they not like polymer they not like the proteins. For example, calcium ion there very very small in size now, if you like to separate this ions then you have to go for a reverse osmosis membrane, which will be having a pore size pretty small in the order of 2-10 Armstrong. Now, if you if you remember the previous you know discussion the reverse osmosis the minimum operating pressure is 25 atmosphere 25 atmospheres on wards.

Therefore, the pump that you are going to use it will it will consume huge amount of electrical power on the other hand if you can remove, if you can bring down the operating pressure the pumping cost are the energy that will be involved in the process will be classically reduced. Therefore, all this if you use the micellar enhanced ultra filtration this micelle loaded with the pollutants added thing the pollutants they will be the separated by membrane.

So, the micelle plus the sol solute pollutants will be separated by the membrane therefore, you are going to get almost the pear solution divide of the pollutants plus the surfactant monomers at the level of C m c. Per since the C m c itself is the very small concentration that will not affect much or if it average you can recover the surfactant by a separate technique. So, that is the idea that is the you know principle of micellar enhanced ultra filtration.

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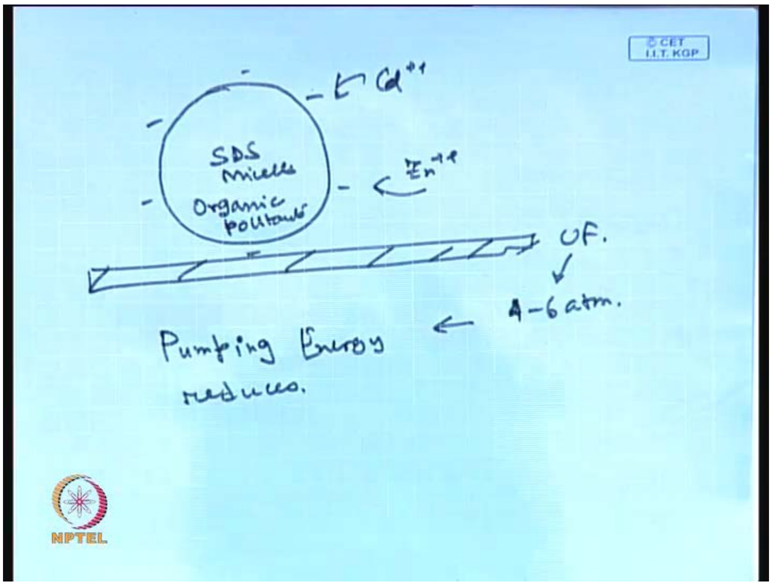

So, this pollutant loaded micelle let say they will be negatively charged like let say S D S micelle. The outer surface you can attach let say cadmium plus plus or let say zinc plus plus. The inner core you can solubilise the phenolic compounds are organic pollutants now, this micelle or larger size they will be separate by a membrane ultra filtration membrane. And these ultra filtration will be requiring and operating pressure in the order of let say 4-6 atmosphere so, the pumping energy will be much much less reduces. So, there is the principle of micellar enhanced ultra filtration and so let us try to quantify various quantity in the various things in the micellar enhanced ultra filtration.

How much what will be the extend of separation of the particular component? Let say anionic pollutants are the organic pollutant in case of micellar enhanced ultra filtration so, that the so that the pin point what is the quality of my product water or what is the second one is what is productivity another is the quality another is the quantity what is the productivity of the process? How much filtrate going to get per metre square membrane area per unit time?

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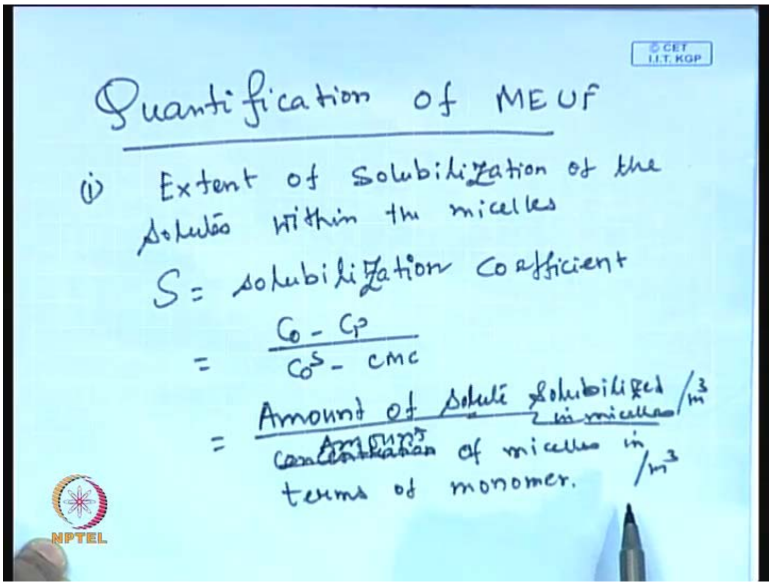

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Quantification of MEUF

(i) Extent of solubilization of the solutes within the micelles

$S =$ solubilization coefficient

$$= \frac{C_0 - C_p}{C_0^s - cmc}$$

$$= \frac{\text{Amount of solute solubilized in micelles}/m^3}{\cancel{\text{Concentration}}\ \text{Amount of micelles in terms of monomer}/m^3}$$

Let us look in to the quantification of anywhere, the first one will about look into the extend of solubilisation.

Extend of solubilisation of the solutes within the micelles in the micelle and this solubilisation coefficient s is defined as solubilisation coefficient, this defined as C not minus C p divide by C not s minus C m c. What C not minus C P? C not minus C p is amount of solute that has been solubilised within the micelle C not is the consent feed concentration of the solute the amount of solute that we are going to have in the feed. And what is C p? C p is the permeate concentration of the solute. So, what is the rest amount? The rest amount much them in trap within the micelle and if you have feed, because you are talking about a ultra filtration membrane of high porosity the pore size much larger.

The talking about the solute of a very low size so whatever, the feed solutes of present in the in the feed side that will be easily permeable to the permeate size. So, there is no effect of concentration polarisation on this particular transport of the solutes in the particular case. Therefore, the if you measure the permeate concentration that will be same as un solubilises free solute concentration in the feed side, because that is easily permeable. So, the concentration across the membrane of the solute is constant that means size is very very small and the size of the, pores of the membrane are quit large around 100 times larger than this.

Therefore, C not minus C p gives a an idea what is the amount of solute that has been solubilised in the micellar per unit volume of the solution. And what is C not s minus C m c? C not s minus C m c gives you the concentration of the total surfactant in the micellar form concentration of micelles in terms of monomer. That means, C not is the total concentration of the surfactant that we have given in the feed and C m c you know so, the rest amount C not s minus C m c it will be also surfactant will be having lower molecular rate it will be fully permeable in the feed side in the permeate side so, across the it will be permeable across the membrane.

So, C not s minus C m c gives an idea what is the concentration of the micelle? Because the rest amount will be the micellar form rest surfactant will be micelle form because the they are not micelle if there in the free form they will be freely come to the permeate side. But that will be allow that the S D S size (( )) because the micelles and the free surfactant the always in the equilibrium the C not s minus C m c is the amount of surfactant that will that will participate in the formation of in the micelle. So, s is the solubilisation coefficient gives an amount of ratio of amount solute that is solubilise in the micelle per unit.

You know if the concentration of micelle it becomes of monomer it is not concentration, if you look the do you permeate meter cube both the cases it becomes to the amount. So, amount of solute solubilise per meter cube divided by amount of micelle in terms of monomer per unit meter cube so it becomes, concentration effectively.

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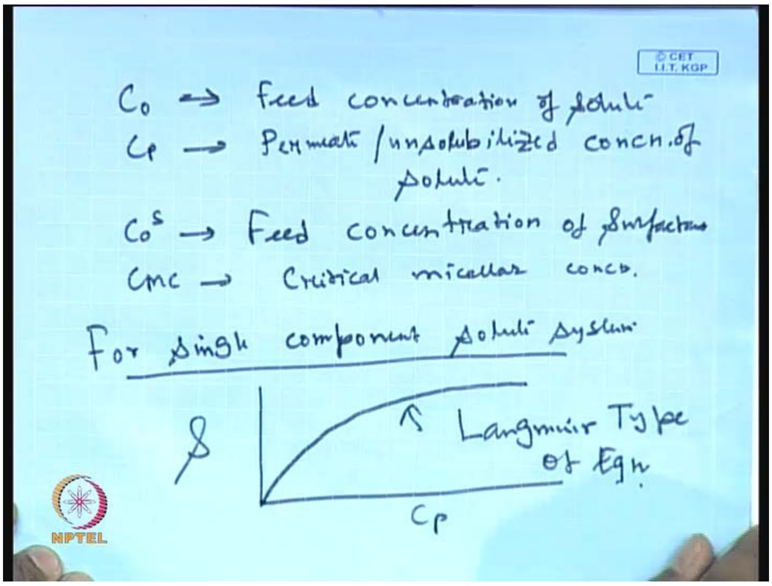

$C_0 \rightarrow$ Feed concentration of solute

$C_p \rightarrow$ Permeate / unsolubilized concn. of solute.

$C_0^s \rightarrow$ Feed concentration of surfactant

$Cmc \rightarrow$ Critical micellar concn.

For single component solute system

So, let us write down the normal nature of clarity, C not is the feed concentration of solute C p is the permeate or un solubilise concentration, because that is same. And C not is the feed concentration of surfactant and C m c is the critical micellar concentration. Now, for single component solute system that means, if you use different concentration of the surfactant on the solute and it measure the permeate concentration. That means, you can evaluate the value of solubilisation coefficient as the function of C p this gives a Langmuir isotherm type of call. And that will be independent of concentration that it will be depending on the temperature so, anyway it will be type of Langmuir type of equation.

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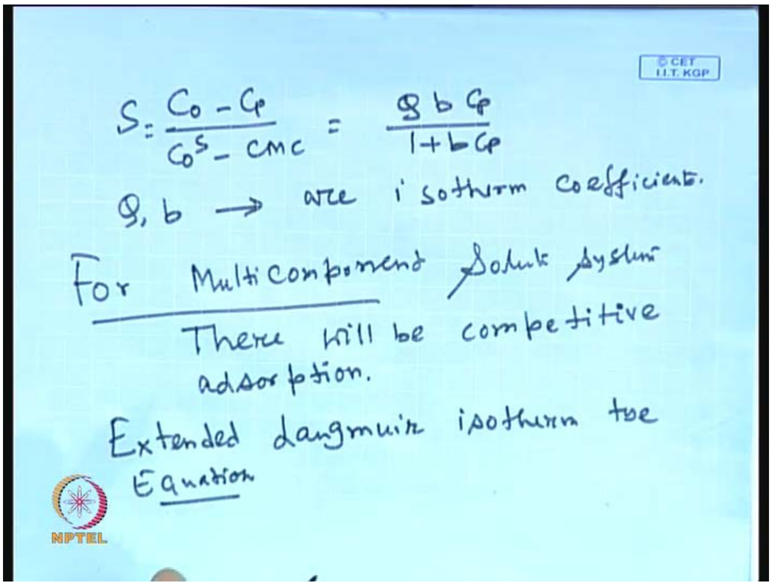

$$S = \frac{C_0 - C_p}{C_0^S - CMC} = \frac{Q b C_p}{1 + b C_p}$$

Q, b $\rightarrow$ are isotherm coefficients.

For Multicomponent Solute System

There will be competitive adsorption.

Extended Langmuir isotherm type Equation

And we can have a Langmuir type of considered in a fitting if this the variation curve C not minus that is the value of you know expression of s C not C minus C m c will be nothing, but Q times b C p divided by 1 plus b C p. This q and b at the isotherm constants that means, you conduct experiment it defined values of concentration and measure the value of s. And then plot the plot it the corresponding C p values will be getting a curve then a fit a curve and it will be getting a Langmuir type of variation. For multi component solute suppose, you have zinc as well as the avail as cal calcium so, there will be competitive absorption.

So, you will be having and you know multi component extended Langmuir type of isotherm. There will be competitive ad adsorption and you can have extended competitive isotherm type equation.

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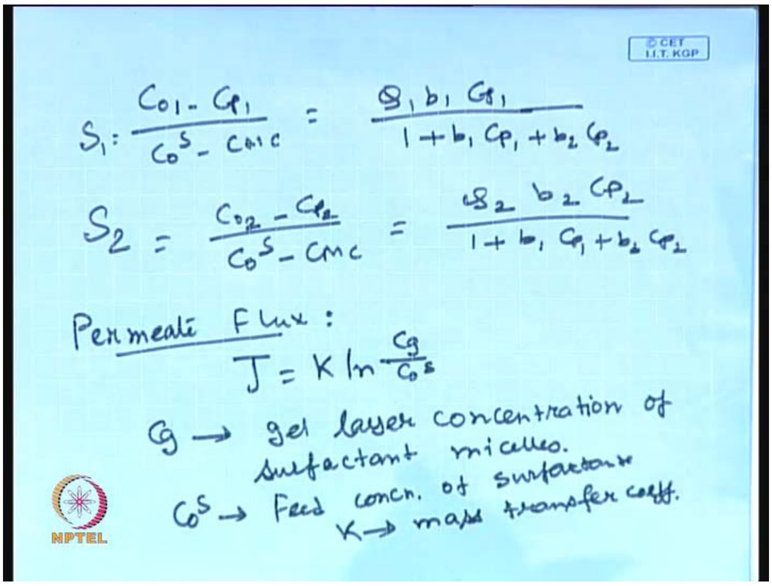

$$S_1: \frac{C_{01} - C_{p1}}{C_0^S - CMC} = \frac{Q_1 b_1 C_{p1}}{1 + b_1 C_{p1} + b_2 C_{p2}}$$

$$S_2 = \frac{C_{02} - C_{p2}}{C_0^S - CMC} = \frac{Q_2 b_2 C_{p2}}{1 + b_1 C_{p1} + b_2 C_{p2}}$$

Permeate Flux:

$$J = K \ln \frac{C_g}{C_0^s}$$

$C_g \rightarrow$ gel layer concentration of surfactant micelles.

$C_0^S \rightarrow$ Feed concn. of surfactant

$K \rightarrow$ mass transfer coeff.

What are these types of extended Langmuir type of Langmuir raise them type of equation? C 0 1 minus C p 1 divide by C 0 s minus C m c that is what is this is the solubilisation coefficient corresponding to component 1 will be nothing, but Q 1 b 1 C p 1 divided by 1 plus b 1 C p 1 plus b 2 C p 2. The extra term in the denominator gives you an idea what is the interaction between this for bit is called a interaction parameter it gives an idea, how the interference of the second component, will affect the solubilisation of the first component within the micelle. So, S 2 similarly, S 2 is plotted C 0 2 minus C p 2 divided by C 0 s minus C m c is equal to Q 2 b 2 C p 2 divided by 1 plus b 1 C p 1 plus b 2 C p 2.

So, this will roughly give you the amount of solubilisation that we are talking about in such system. Next we talk about the permeate flux so, that that will give you the quality of the permeate the isotherm will give you the quality of the permeate. What this isotherm will give you? Basically it tells you if you know the value of C 0 1 and C 0 2 that means feed values of the solute and if you know the concentration of the surfactant. Then by solving this equation you can predict by solving simultaneous solvent this equation you can predict what is the value of C p 1 and what is the value of C p 2. If you know the isotherm that mean if you suppose, you know the isotherm of the particular system and you know the concentration of the solutes two solutes three solutes.

Whatever, in the in the feed stream and will not the concentration of the surfactant and you know the value of the C m c is the property of the surfactant. So, you can solve this two equation simultaneously and get the values of the you know concentration of the solute in the permeate and you can get the quit of the permeate. So, next you get the quantity of the permeate is the permeate flux that is the productivity of the through put of the system, this is known as this quantify by the quit J is equal to K l n C g by C not C. Now, it is assume that the surfactant micelle will deposit of the membrane surface and format gel type of layer over it, at the filtration is entirely control by the same as gel layer control ultra filtration type of thing.

So, at the study state you can have the you can you can quantify the value of the permeate flux has J is equal to K l n C g by C not s as tern previously. And you know you can find out the value of C g you can you can conduct experiment the steady state experiment with different concentration of the feed surfactant and measure the permeate flux. The steady state permeates flux and then plot steady state permeates flux as the function of feed concentration is the similar plot. Then you get the will be will be getting a straight line and if you extend the if you if you establish the straight line the point you where it you know curves the x axis that will you give you the gel layer concentration.

The same way you have measure the gel layer concentration earlier in case of the protein of the polmeric solutes. So, C g is the gel layer concentration of surfactant micelles C not s is the feed concentration of surfactant monomers and C g is basically, gel layer concentration surfactant in terms of monomers. And K is the mass transfer coefficient the same way we have determined the mass transfer coefficient earlier, that mean first you have seen whether it is flow is laminar are turbulent. If it is laminar is the either equation to determine the mass transfer coefficient if it is turbulent again go to the detect bold as type of correlation to estimate the mass transfer coefficient.

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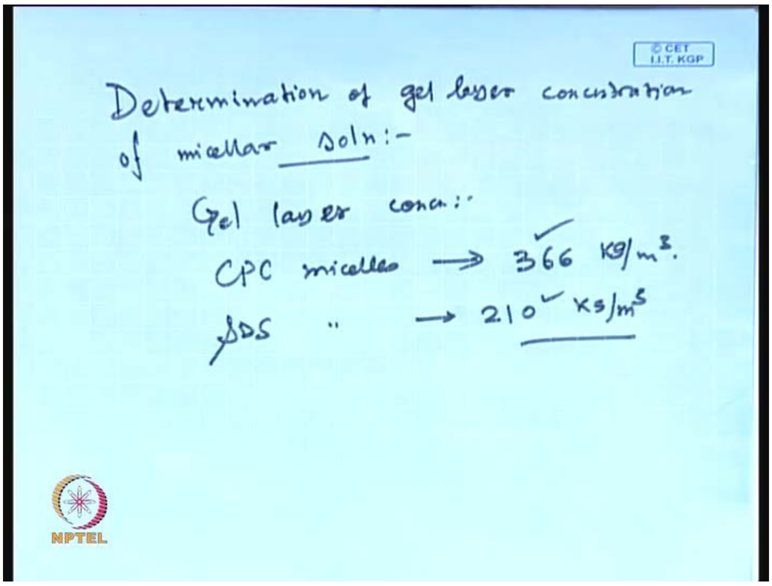

Determination of gel layer concentration of micellar soln:-

Gel layer concn:

CPC micelles → 366 kg/m³.

SDS " → 210 kg/m³

Now, determination of gel layer concentration is quit important of micellar solution is very important. The typical value of gel layer concentration for C p micelles this is around 366 kg per metre cube, on the other hand for S D S micelle it is 210 kg per meter cube. And we have we conduce experiment various concentration of the micelle and do a under same stirring speed and the mass transfer coefficient. We conduct the steady we made the steady state permeate flux from the plot will be getting the from the extra operation of the data we can get the values of the of this concentrations.

Now, once you have this you know concentration of then will be able to predict the quantitatively what is the permeate flux of the filtration rate? Now, in presence of the counter ion there several complicate phenomena, those will occur during micellar enhanced ultra filtration those will affect the performance of the system. In fact you will be did discussion all this effect in detail in the in tomorrow class and will be solving some of the problem to quantify how to quantify such system in detail. So, stop in to next class I will move in the next class for the discussion on this particular topic. Thank you.