Novel Separation Processes
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Lecture No. # 22
External Field Induced Membrane Separation Processes

So, good morning everyone. So now, will be moving on to the next topic that is external field induced membrane base separation process is. In fact, these types of separation processes are very important when we are talking about the filtration of colloids. And this colloids are basically charged molecules, and there are number of phenomena that will be occurring due to a during the filtration of the colloids molecules for a, because these colloids at the charged. So therefore, in inter molecular forces, electro static forces rate, long range, short range with the with the membrane surface between the molecules themselves and things like that.

Now, when did the some fundamental aspects of various colloids colloidal particles, and therefore if you have an external electric field present in the system, there are certain changes that will occur. Now, if you have a charged surface, and it is if you have two charged surfaces, and if there is a relative velocity between these charge surfaces, there are several phenomena those will be occurring at a time. These phenomena in a group are called electro kinetic effects.

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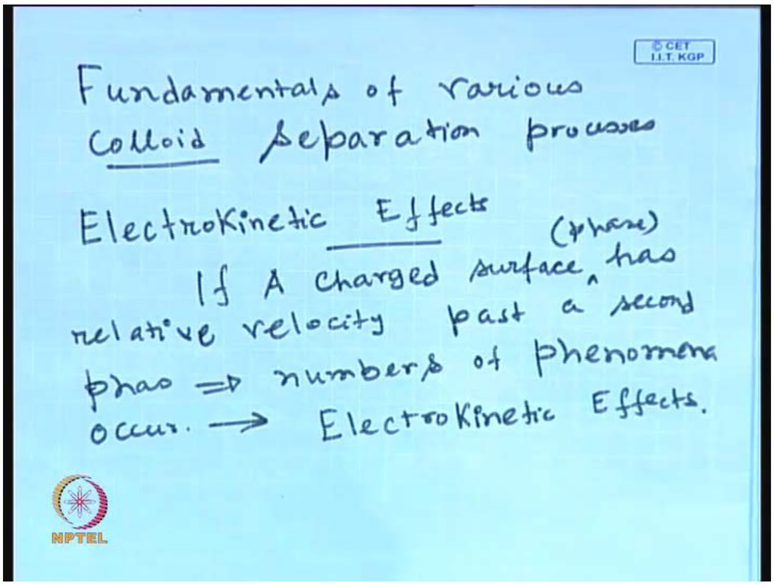

Fundamentals of various Colloid separation processes

Electrokinetic Effects

If A charged surface (phase) has relative velocity past a second phase ⇒ numbers of phenomena occur. → ElectroKinetic Effects.

So, let us look into the fundamentals of various colloid separation processes fundamentals of various processes. So the first one, the first effect of the charge colloids are called electro kinetic effects. What are the electro kinetic effects? If you have a charged surface, if a charged surface has relative velocity past second surface or face, this is charged surface or charged phase past a second surface or phase, then number of phenomena numbers of phenomena occur, and they are grouped as they are known as electro kinetic effects. So, what is what is the basically the definition electro kinetic effect? If you have a charge surface or phase, and then it moves past another phase, then the number of such phenomena those will occur and all of them are group and call electric and group under the category of electro kinetic effects.

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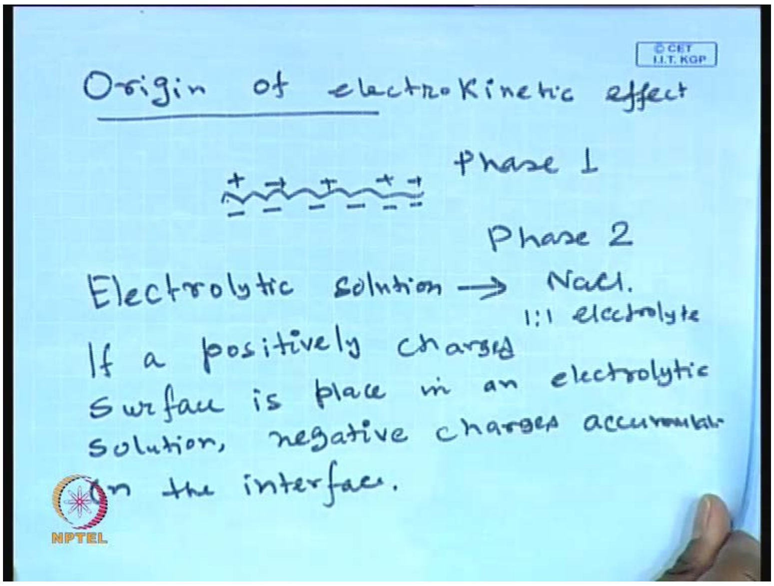

Origin of electrokinetic effect

$+ + + + +$ Phase 1

$- - - - - -$

Phase 2

Electrolytic solution → NaCl.

1:1 electrolyte

If a positively charged surface is place in an electrolytic solution, negative charges accumulate on the interface.

Now, let us look in to the origin of electro kinetic effect. Now, if you suppose we are we are having two phases; this is phase number 1; and this is phase number 2. And these two phases, it will be having the… Suppose, there are positive charges; that means, if you have an interface for example, if you have a positively charged surface placed into an electrolytic solution; electrolytic solution means, you will be having a sodium chloride solution basically, a 1 is to 1 electrolyte is sodium chloride solution, electrolytic solution for example Nacl; this is 1 is to 1 electrolyte.

That means, both of the species, ionic species sodium and chloride they will be having a balance is 1. Now, if you if you place it positively charged surface in a electrolyte solutions; now negatively charged particles are negative charges will accumulate on the interface. So, why they will be accumulate, because of the electrostatic across the forces. Now, if a positively charged surface is placed in an electrolytic solution negative charges accumulate on the interface. There is the first manifestation of putting a positively charged surface in an electrolytic solution, and what is the second manifestation? The second manifestation is that the concentration.

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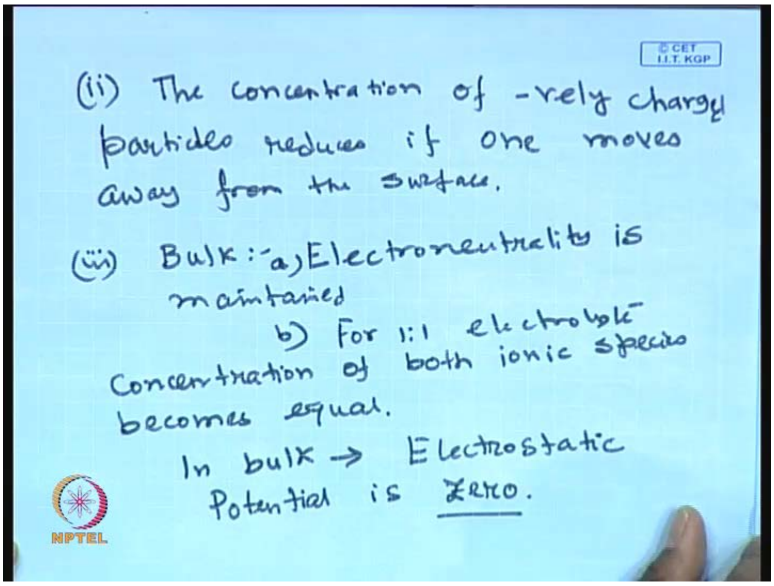

(ii) The concentration of -vely charged particles reduces if one moves away from the surface.

(iii) Bulk :- a) Electroneutrality is maintained

b) For 1:1 electrolyte concentration of both ionic species becomes equal.

In bulk → Electrostatic Potential is zero.

So therefore, the concentration of negatively charged particles or ions maximum at the interface. And second manifestation will be that the concentration of negatively charged particles reduces if one moves away from the surface. And what happens in the bulk? In the bulk electron neutrality will be maintained is maintained the first one. Secondly, concentration of positively charged particles, negatively charged particles will be equal if you have a 1 is to 1 electrolyte. For 1 is to 1 electrolyte concentration of both ionic species becomes equal, and the if the bulk of the solution becomes electro neutral. Now, in the bulk in the bulk electrostatic potential is taken as 0 electrostatic potential is taken as 0.

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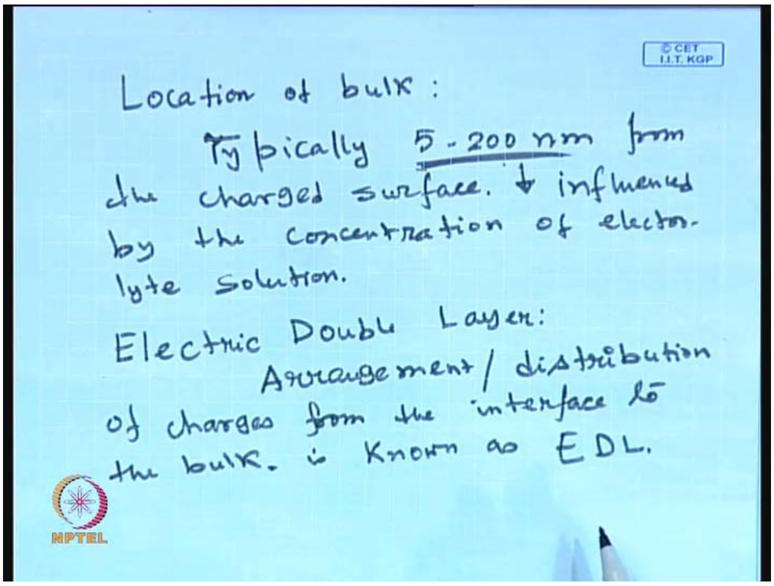

Location of bulk :

Typically 5 - 200 nm from the charged surface. & influenced by the concentration of electrolyte solution.

Electric Double Layer:

Arrangement / distribution of charges from the interface to the bulk. is known as EDL.

And what is the bulk? Bulk is situated at a system between 5 to 10 nanometre from the surface. Location of the bulk location of the bulk is typically 5 to 20 nanometre from the charged surface, 5 to 200 nanometre from the charge surface. And what will dictate this distance? This distance is dictated it is influenced by the concentration of electrolyte solution whether it is 0.1 molar or 1 molar sodium chloride solutions. That will dictate this distance our rearrangement of the arrangement or distribution of the charges near the interface will occur. So now, will come to the definition of Electro Double Layer or EDL.

Definition of Electro Double Layer is now the arrangement or distribution of charges from the interface to the bulk is known as electric double layer. And typically, the electric double layer thickness will be 5 to 200 nanometre based on the concentration of the electrolyte that you are having. So, what is electric double layer EDL? EDL is basically so whenever you will be placing a charged surface in an electrolytic solution, there will be radiate situation of the charges between the interface and the bulk of the solution. These particular join will be having a typical thickness 5 to 200 nanometre based on the concentration of the electrolyte. That particular layer is known as the origin is known as the Electric Double Layer.

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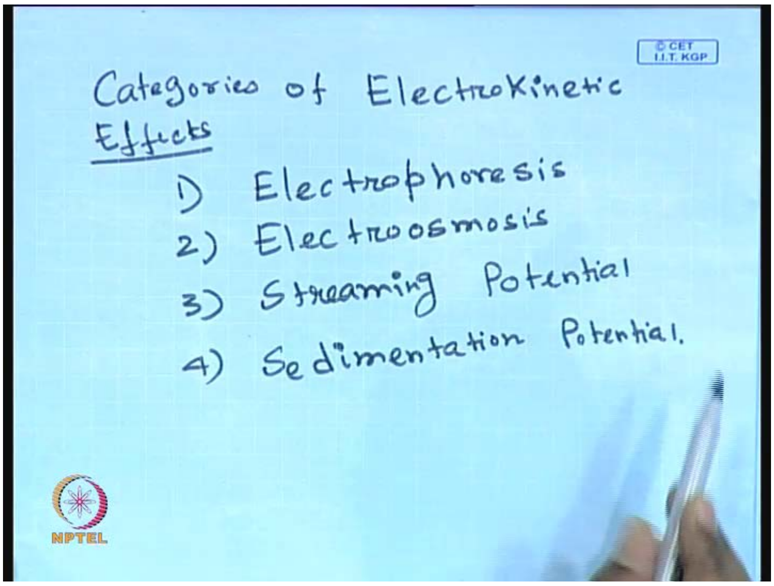

Categories of ElectroKinetic Effects

1) Electrophoresis
2) Electroosmosis
3) Streaming Potential
4) Sedimentation Potential.

Now, let us look into the various categories of electro kinetic effects. Typically, there are four categories of electro kinetic effects; one is Electrophoresis; second is Electro osmosis; third is streaming potential; fourth one is sedimentation potential. The four of them are present electrophoresis, electroosmosis, streaming potential, sediment sedimentation potential depending on the situation. Now, will be look in to the definition of each and every category and see what are the difference, and what are the various the manifestation, and what are the conditions to establish one of this electro kinetic effects being present in your system.

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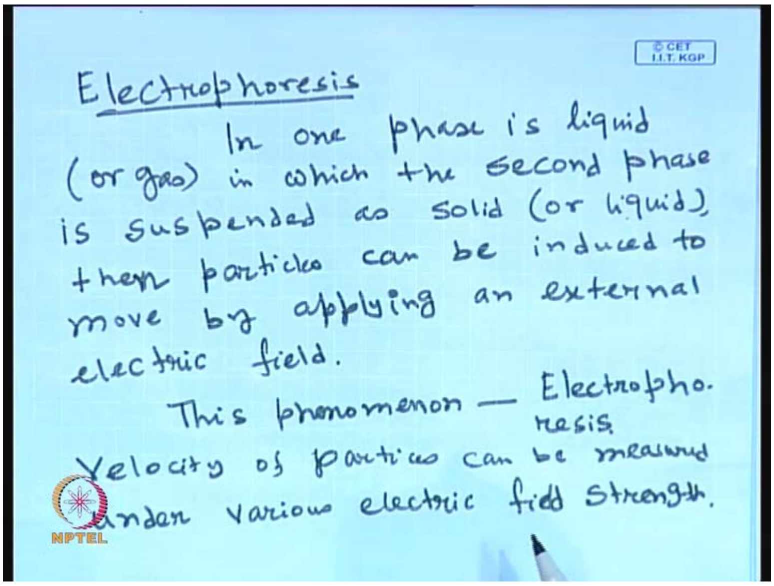

Electrophoresis

In one phase is liquid (or gas) in which the second phase is suspended as solid (or liquid), then particles can be induced to move by applying an external electric field.

This phenomenon — Electrophoresis

Velocity of particles can be measured under various electric field strength.

The first one is electrophoresis. If one phase is liquid or gas is liquid or gas in which, the second phase is suspended as solid or liquid then particles that means, the solid particles that means, if you are talking about second phase of the solute particles if the first particle is liquid. You are talking about the liquid for droplets if the of the second phase if the first phase is gas. So the combination is liquid solid that two phases or gas liquid. Then a particle, these particles means either solid particles, if the phase 1 is liquid or liquid droplets. If the phase 1 is gas then, particles can be induced to move by applying an external electric field. This phenomenon is known as electrophoresis. This simply means, if you have a liquid stream for example, if you have aqua solution with electrolytic aqua; if you have a aqua solution and if you have charge particles for example, protein etcetera.

Now, you apply external electric field then, this charge particle will move from one to the other. This phenomenon is known as the electrophoresis, and you can measure the velocity of electrophoresis. Velocity of particles can be measured under various electric field strength. That means, you track a particle and see how much distance is cover some per unit time under an external electric field; let say e 1 and you can increase the electric field to e 2.

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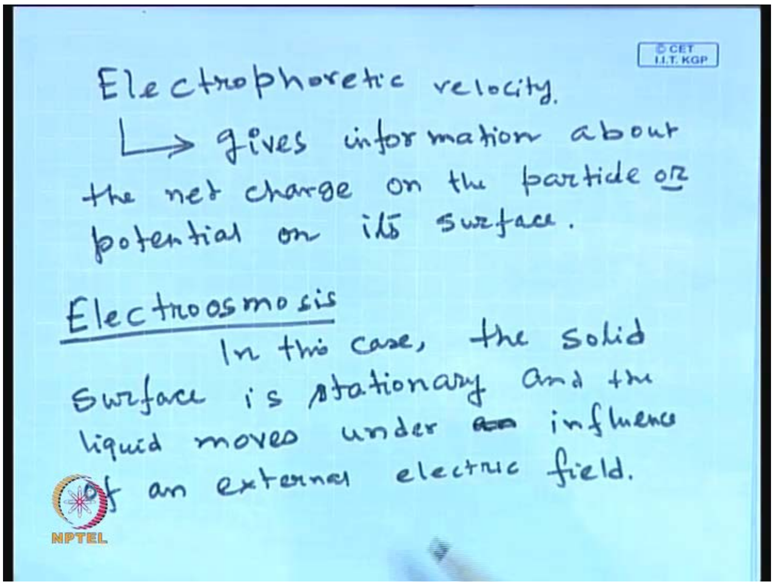

Electrophoretic velocity.

↳ gives information about the net charge on the particle or potential on its surface.

Electroosmosis

In this case, the solid surface is stationary and the liquid moves under influence of an external electric field.

And can measure the particle velocity. This velocity is known as the electrophoretic velocity. What this electrophoretic velocity electrophoretic velocity in for are gives the formation? It gives information about the net charge on the particle or potential or it is surface. So electrophoretic measure velocity than we can lead, can give you information about the net charges residing on the particle or the net surface potential it will be having. So that is important, because in under some calculations you will you will see later on that, what is the net charge on the particle or surface potential are important in some subsequence calculations. They are you need to measure the electrophoretic velocity and therefore, electrophoresis required. Next phenomenon is known as electro osmosis. Now what is the electroosmosis? Osmosis in this case, the solid remains stationary in this case the solid surface is stationary, and the liquid moves under an under influence of an external electric field. So, there is the difference between the electrophoresis and electroosmosis. In electrophoresis, the solid particles used to move in the liquid stream under the presence of external electric field. In this case, the liquid stream moves in presence of when the solid surface is stationary under the influence of an external electric field.

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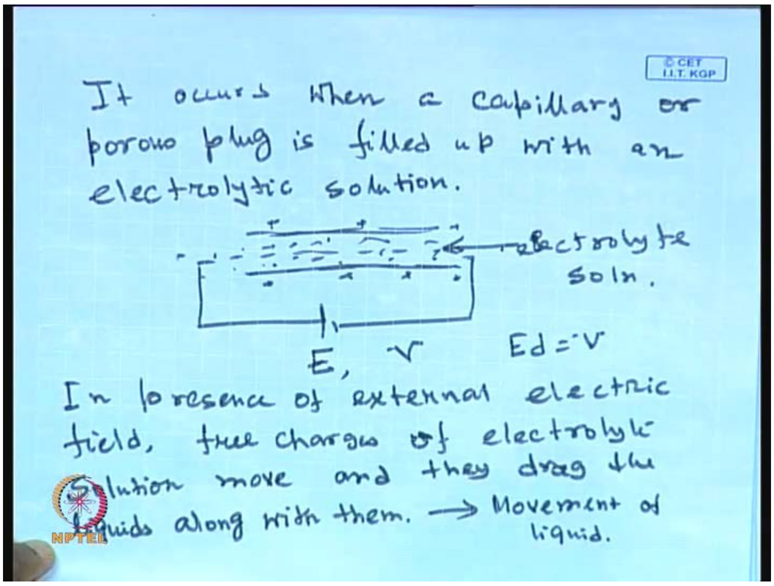

It occurs when a capillary or porous plug is filled up with an electrolytic solution.

In presence of external electric field, free charges of electrolyte solution move and they drag the liquids along with them. → Movement of liquid.

So, one it one it this can occur. It occurs when a capillary or porous plug is filled up with an electrolytic solution. That means, you are having a porous plug or capillary. A capillary where, let say it is very small capillary with the surface are charged. And you are having a electrolytic solution here; it is filled up with electrolytic solution. Now if you apply an external electric field of let say voltage V and strength E. And the relation between E and V is nothing, but E times d is equal to V where d is the distance between the two of the of the of the channel. Now, if you have any electrolytic solution kept in the porous plug; electrolyte solution means, they are containing free charges like sodium chloride solution they containing free charges. Now, if I apply an external electric field, the charged particle will move from one end to the other. In the in response to the external electric field, the charge particles will move and they will drag the liquid along with them causing the flow of the liquid. So this is known as electroosmosis. So, in presence of external electric field, free charges of electrolytes electrolyte solution move and they drag the liquids along with them resulting into a motion of liquid movement of liquid. This is known as this phenomenon is known as electro phoro electro osmosis.

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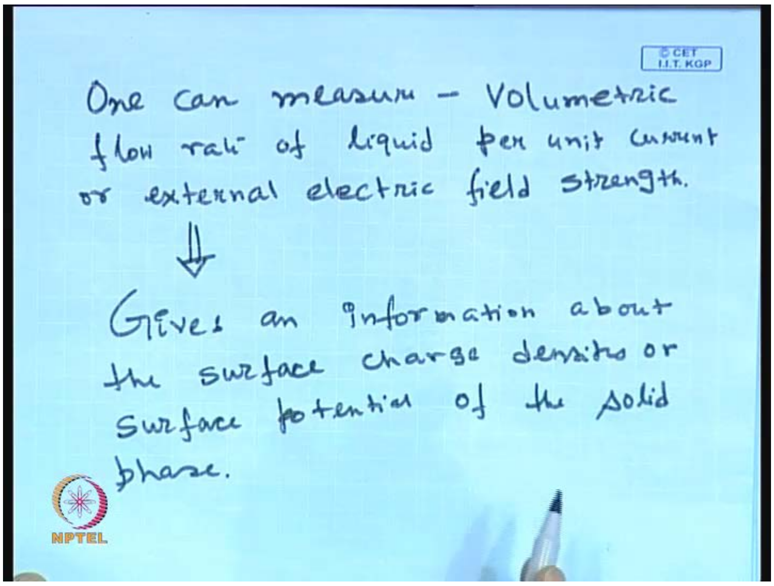

One can measure - Volumetric flow rate of liquid per unit current or external electric field strength.

⇓

Gives an information about the surface charge density or surface potential of the solid phase.

Now, one can measure the volumetric flow rate one can measure volumetric flow rate of liquid per unit current or external fields electric field strength. So, we can measure the volumetric flow rate or electro osmotic flow rate of the liquid per unit current or per unit external electric field strength. This will give me an information about the surface charge density or surface potential of the solid phase. So, once you measure the electro osmotic volumetric flow rate that gives information about the vole surface of the potential of the solid capillary, charged capillary or the surface charged electric charge density of the capillary.

So, one can get an information about the how much potential, surface potential of the capillary of what is the net amount of the charge density. That means, charge per units square meter of surface is present on that. So, if you are talking about nano filtration membranes, where the membrane surface basically charged, and by this method by measuring the electro osmotic flow rate, one can measure the inlet potential of the of the capillary are the force. Now, one can do the during the fabrication of the membrane or the casting of the membrane, one can change the operating condition suitably and can monitor or can have suitable electrical charges, and can have the desired properties regarding the retention of particular type of solute and things like that. So electroosmosis is very important as per as the membrane filtration is concerned.

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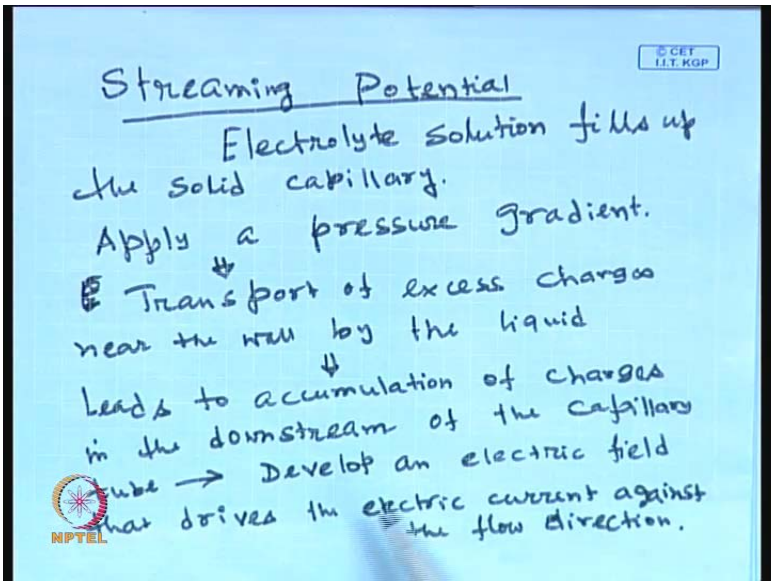

Streaming Potential

Electrolyte solution fills up the solid capillary.

Apply a pressure gradient.

⇓

Transport of excess charges near the wall by the liquid

⇓

Leads to accumulation of charges in the downstream of the capillary tube → Develop an electric field that drives the electric current against the flow direction.

Next, electro kinetic phenomenon that will be studying is the streaming potential. In streaming potential now we are… In this case, we will not be applying any external electric field, will be applying an external pressure. So, here also the electrolyte solution fills up the solid capillary, and in this case we are not applying, it is just reverse of electroosmosis. You are not applying in a external electric field, we are apply an delta p apply a pressure gradient, you are not using an external electric field, we are applying a pressure gradient, let us see what happens? There will be access charges present right; if you have a solid surface or solid capillary that will be fix filled up the electrolytic solution, the capillary surface inner surface will be charged. So counter charges will be counter ions from the electric solution will be concentrate on the close to the surface forming the electric double layer. Beyond the electric double layer, the surface the ions are free.

Now, why when you apply external pressure gradient the exist charges, this will lead to transport of transport of excess charges near the wall by the liquid movement by the liquid, because you are you are you are applying the pressure gradient means, the liquids will move and in the mean time when they will move, they will take the excess charges along with them, and these will lead to leads to accumulation of charges in the downstream of the of the channel or of the of the capillary tube. So, when the excess charges will be present in a system that will cause the development of electric field. So, this will develop an electric field that drives the electric current against the flow direction. So, accumulation so the excess charges will be carried over by the flow of the feed that is generated by the delta p or the pressure gradient and the excess charges will be will be accumulated in the downstream of the tube forming development build up of electric field, that will cause an electric current flow against the flow direction and soon.

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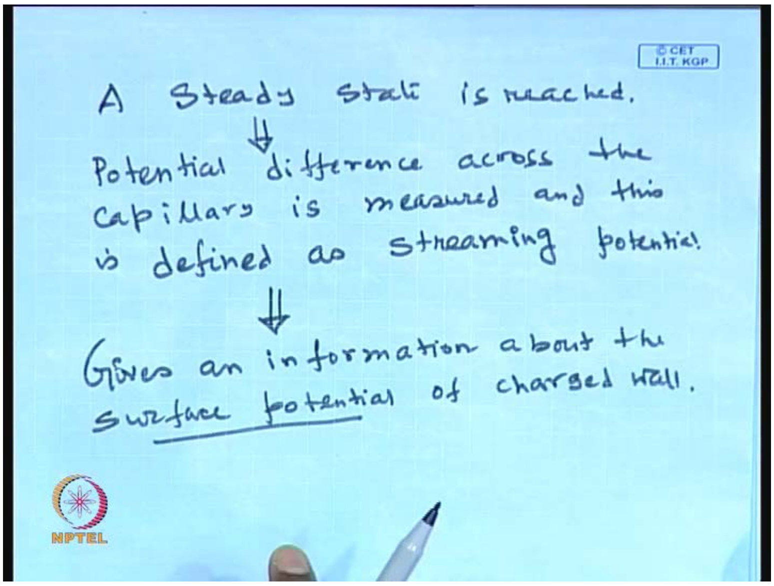

A Steady State is reached.

⇓

Potential difference across the capillary is measured and this is defined as streaming potential

⇓

Gives an information about the surface potential of charged wall.

A steady state is reached a steady state is reached. At the steady state, the potential different across the capillary is measured, and this potential difference is defined as streaming potential. Now, why will you measure the streaming potential? The streaming potential will give you information about the surface potential of the charged wall. It can give the surface potential or it can give the electric charge density. That means, charge in coulomb per meter square of the wall. Now both electroosmosis and streaming potential measurement will give the information about the electric potential of the charged wall or charge density of the charged wall, but what is the difference between the two? In one case, where applying an external in both the cases we are putting an electronic solution in an in a in a charged in a in a capillary tube or the walls are charged. In both the cases, the liquid is moving at the solid surface is stationary, but in the case of electroosmosis where applying an externally electric field. In the case of streaming potential we are applying an external special difference.

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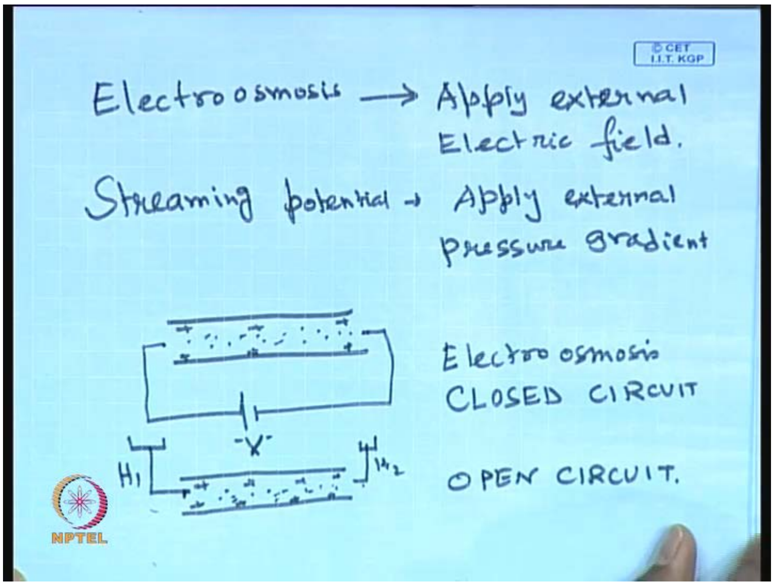

Electroosmosis → Apply external Electric field.

Streaming potential → Apply external pressure gradient

Electro osmosis CLOSED CIRCUIT

OPEN CIRCUIT.

So, in case of electroosmosis we are using applying external electric field. In case of streaming potential we are applying external pressure gradient. How will you physically you know realize these two situations? That means, the electric circuit is complete or it is closed in case of electro osmosis, and electro circuit is open in case of streaming potential. That means, if you have a channel or a tube the where the walls are you know poor charged and it is filled up with electrolytic solution. Now, this is the case of electro osmosis; you are applying an external electric field that means, both the two ends are basically connected to different poles of a battery. This is the case of electroosmosis where the circuit is closed, but talking about a closed circuit.

On the other hand, the situation is identical as far as the physical system is concerned that is, we will we will be having a electrolytic solution filled up in a porous plug, and in this case, the electric circuit is open and we are applying a pressure gradient. How will you applying a pressure gradient? Either using a small pump or you know or you just make a difference in level of the two reserves. That means, the pressure here is rho G H

1 if this height is H 1; and this height is rho G H 2. If there is the pressure difference between the two. So, somehow we have to apply, you have to generate a pressure difference between the two ends then, the system is known as the streaming potential and it is open circuit, because this circuit is not connected with the electric voltage source external voltage source. So, it is open circuit. So, there is the difference between the electroosmosis and streaming potential.

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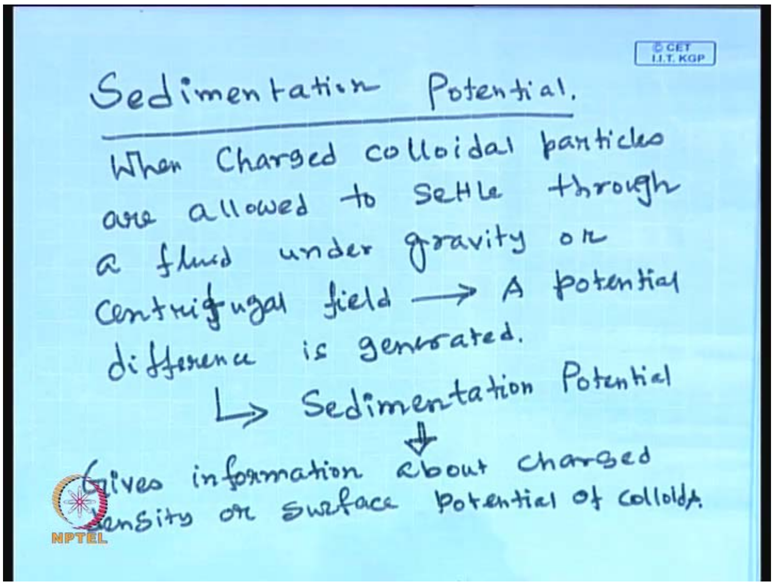

Sedimentation Potential.

When Charged colloidal particles are allowed to settle through a fluid under gravity or centrifugal field → A potential difference is generated.

↳ Sedimentation Potential

↓

Gives information about charged density or surface potential of colloids.

The next one will be talking about the discussing the next in the last one is sedimentation potential. What is sedimentation potential? Suppose, charged colloids when charged colloidal particles are allowed to settle through a fluid or let say liquid under gravity or centrifugal field. That means, these happens the centrifugal as well field. A potential difference is generated, because the charge particles will be settling down. So, there will be there will be difference in potential between the two points in the field. A potential difference is generated; this potential difference is known as the sedimentation potential. One can measure the sedimentation potential and the measurement of the sedimentation potential gives you information about charged density or surface potential of colloids. So there are four; all this four phenomena the electrophoresis, electroosmosis, streaming potential and sedimentation potential they clubbed; they are grouped together under the category of electro kinetic phenomena, and this electro kinetic effects can be generated by different you know physical situations and based on that will categorised them, and measurements are surface potential are something measurement of this various thinks like that for example, it is a flow rate in a case of electro osmosis. It is the velocity of the particles in case of electrophoresis. It is the sediment it is the electric potential in case of streaming potential or sedimentation potential measurements of all this quantities will give you quantify the net charge density of the charge particles or the surface potential on them or the charge density or surface potential of the solid wall in case of streaming potential are and are electroosmosis.

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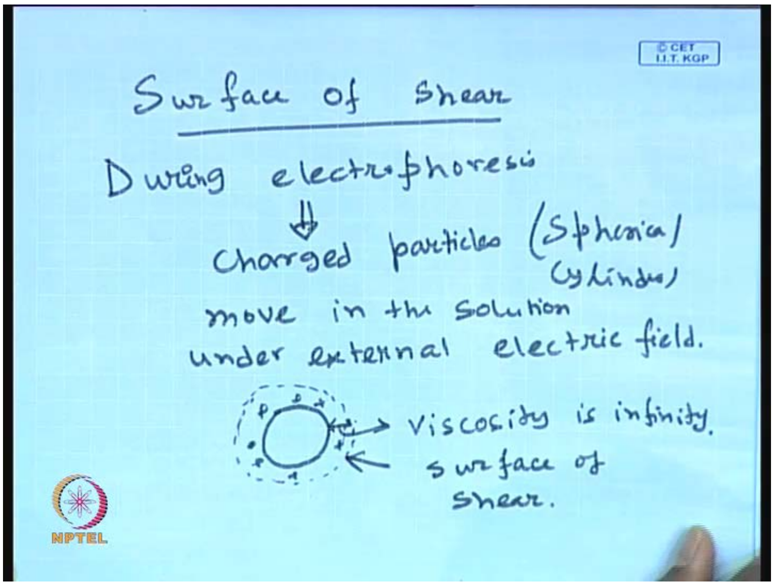

Surface of Shear

During electrophoresis
⇓
Charged particles (Spherical/ cylinder)
move in the solution
under external electric field.

viscosity is infinity.
surface of shear.

Now next, we talk about the surface of shear and Zeta potential. What is a surface of shear? Now, when during electrophoresis or let us talk about the electrophoresis. The particles the particles the charge particles may be spherical or cylindrical spherical cylindrical or any other shape. When they move in the liquids they surface of shear is nothing, but the imaginary surface where it is considered lying close to the solid surface. That means, during electrophoresis the charge particle move right charge particles move in the solution under the external electric field.

Now, there is a particular region for example, this is a this is a shear; this is a positively charged shear. Now it is moving in the liquid stream and there is a surface around the solid shear between this solid shear the viscosity is infinity. What you mean, by viscosity is infinity? That means, an external layer of the fluid will be always attaching of this charged particles and it will move along with it. This so there is no surface or shear and this is these surface the external surface is called surface of shear. What do you mean, by viscosity is infinity? Within this within the surface of shear, the viscosity is infinity means, it cannot move under the under external force. That means, this particular layer is permanently attached on the charged particle and moves along with it.

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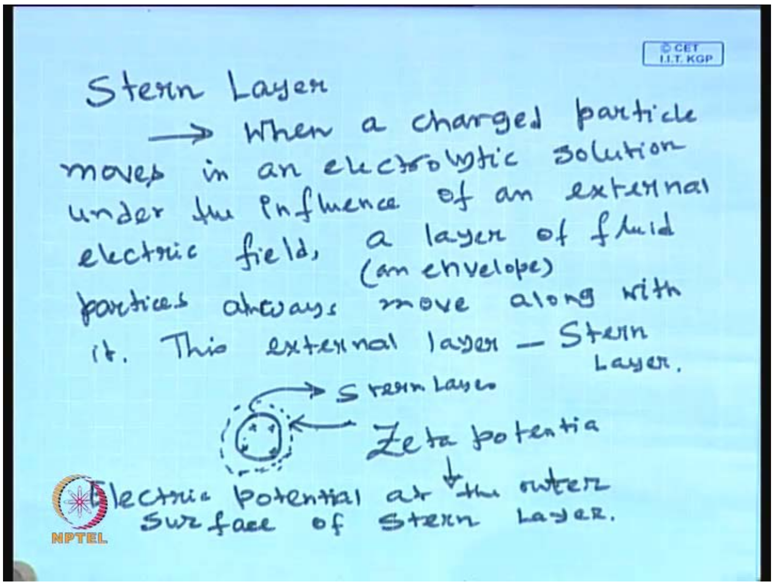

Stern Layer

→ When a charged particle moves in an electrolytic solution under the influence of an external electric field, a layer of fluid (an envelope) particles always move along with it. This external layer — Stern Layer.

Electric potential at the outer surface of Stern Layer.

The this particular the the the this particular layer is known as the stern layer. So, what is stern layer? Stern layer is when a charged particle moves in an electrolytic solution under the influence of an external electric field, a layer of fluid particles or an envelop of field particles of field particles always move along with it. This external layer is known as the stern layer. And the potential surface potential on the outside surface potential in this stern layer is known as the zeta potential. That means, this is the charge particle and you will be having an external layer mainly constituted by the counter ions. That means, negatively charged ions it is moving along with it, and the potential on this outside; so this layer this particular layer is known as the stern layer. And the outside surface is known as the potential on this outside surface is known as the zeta potential. So, the definition of the zeta potential is the potential electric potential at the outer surface of stern layer.

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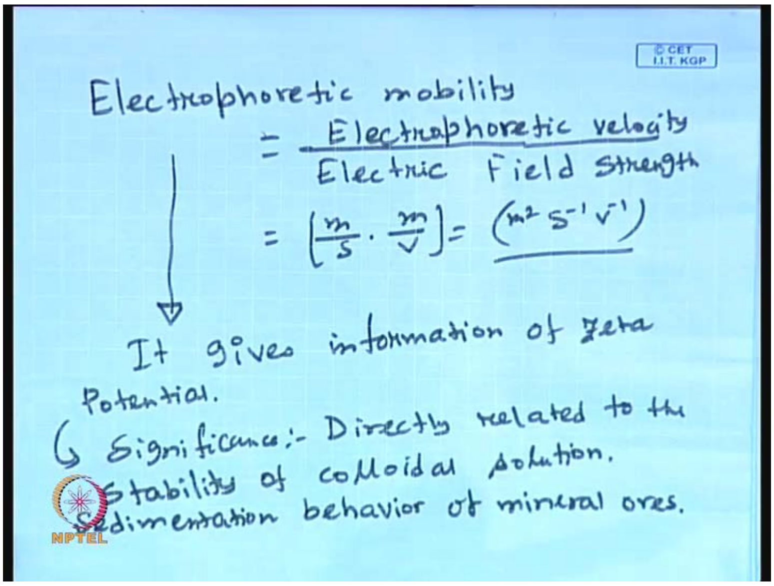

Electrophoretic mobility

$$= \frac{\text{Electrophoretic velocity}}{\text{Electric Field Strength}}$$

$$= \left[\frac{m}{s} \cdot \frac{m}{V}\right] = (m^2 s^{-1} V^{-1})$$

It gives information of zeta potential.

↳ Significance:- Directly related to the stability of colloidal solution.

Sedimentation behavior of mineral ores.

So, measurement of electrophoretic mobility will give you an idea of zeta potential right. The electrophoretic mobility; what is the definition of electrophoretic mobility? We are talked about the electro kinetic velocity when you discussed about the electrophoresis, we talked about electrophoresis velocity and electrolyte mobility is nothing, but electrophoretic velocity per unit electric field strength. So, the mobility will be having the definition of electrophoretic velocity per unit external electric field strength electric field strength. So, what is the electro velocity unit of electro velocity? The meter per second and electric field electric field strength will be having a unit volt per unit per meter. So, this is volt per meter; so it is will be having a unit of meter square second inverse volt inverse, twice the unit of electrophoretic mobility.

So, if you can measure the electrophoretic mobility that gives the clear cut idea about the zeta potential. So, it gives information of zeta potential, and what is the significance of zeta potential? Significance of physical significance of zeta potential is that it is related to the stability of the colloidal solution; directly related to the stability of colloidal solution. That means, if you have a colloidal solution the outsources suppose, there are several particles having the having more or less zeta potential with the similar, charges. So, they will repair each other and that whole solution become stable. Now, if you add some coagulant from the outside that will form a negative charged coagulant that will form complexes with the charge particles, and these charge particles will be the whole complex will grow bigger in size as more colloids will be attached to it and therefore, the whole think will be settled down and the colloidal stability will be decreasing.

So, if you would like to destabilize a colloidal solution, you have to add the coagulant from outside that will give the that will basically precipitated the whole, it becomes neutral and it becomes the density becomes larger and higher, and it become precipitated and the colloidal solution will be destabilized. Next, the behaviour so sedimentation behaviour of the mineral ores can be is one of the filled sedimentation behaviour of mineral ores processing of the mineral etcetera; the zeta potential will be really required. So, if the zeta potential is very high the those of coagulant must be very high. So, that they will be precipitated; they will be added and it will be precipitated. So, measurement of zeta potential has direct implication regarding the stability of the colloidal solution.

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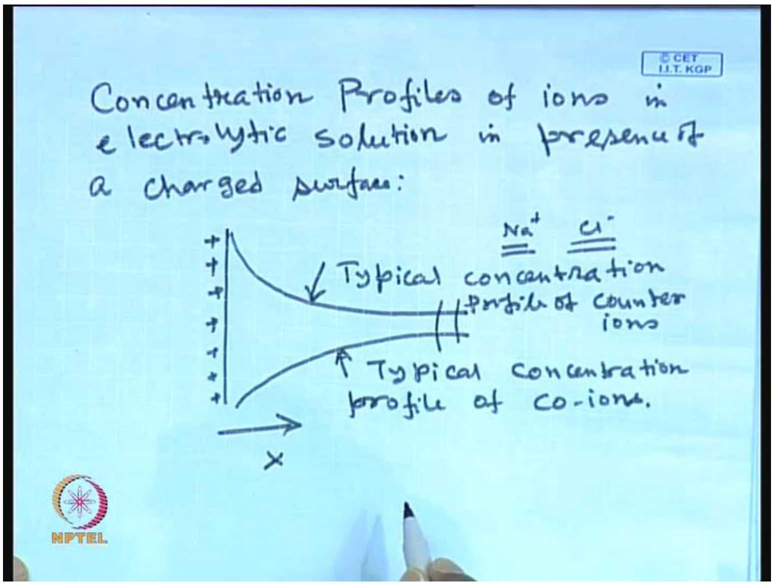

Concentration Profiles of ions in electrolytic solution in presence of a charged surface:

Next, we go from go for some quantification. The quantification is the first quantification is the concentration profile of ions of ions in electrolytic solution in presence of a charged surface. So, that means, there is a electrolytic solution present here, and you are putting a surface which is positively charged. So, the counter ions or the… In a electric solution let say Nacl will be having plenty amount of Na plus and Cl minus ions there, and negatively charged ions will be accumulating over this surface they are called. So, if this surface is positively charged, this negatively charged ions are called counter ions. If this surface is positively charged then, positively charged ions are called co ions. On the other hand, if you if this surface is negatively charged the negatively charged ions will be co ions and positively charges ions will be counter ions. So, opposite charges are basically counter ions and similar charges are co ions.

So, the concentration of the counter ions will be maximum at the surface, because more counter ions will be accumulated there, and it will be decreasing exponential towards the bulk. Similarly, so therefore, this will be the typical concentration profile of counter ions, and this will be typical concentration profiles of co ions co ions. So, initially near the surface the co ions will be minimal and it will be increasing, and at the bulk they will be equal; means the overall nutritive will be maintained will be coming to that. So, X is the distance from the surface towards the bulk. This is the typical charge distribution in an electrolytic solution when a charge surface is in must or inserted into the electrolytic solution.

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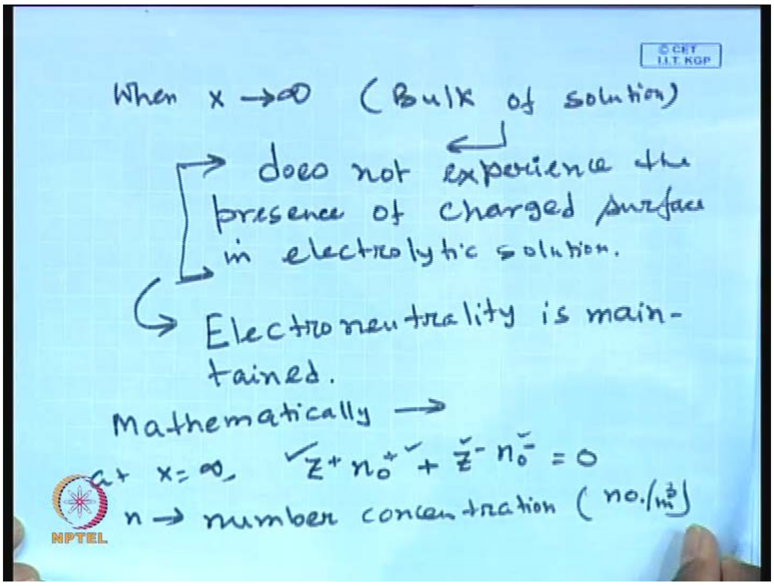

When $x \to \infty$ (Bulk of solution)

does not experience the presence of charged surface in electrolytic solution.

Electroneutrality is maintained.

Mathematically →

at $x = \infty$, $z^+ n_0^+ + z^- n_0^- = 0$

$n \to$ number concentration (no./m^3)

Let us see at infinity what happens when X terns to infinity. What is infinity? It is the bulk of the solution; and what is the bulk of the solution? Bulk of the solution means, at infinite distance the presence of that charged surface is not felt. That means, bulk of the solution does not experience the presence of charged surface in electrolytic solution. That means, electro… What does that mean? That means, there is no distribution of the charges and electro neutrality will be maintained is maintained. Now, this express this whatever we have just discuss now, this whole thing can be described mathematically by a single equation; at X equal to infinity; Z plus n 0 plus plus Z minus n 0 minus will be is equal to 0. That means… What is n 0 plus? n 0 plus is the concentrate is the number concentration; n is basically the number concentration. Number concentration means, number of ions number per unit meter cube of the solution; number of ions per unit volume of the solution that is the number concentration. From the molar concentration, you can get the number concentration, because one mole contain Avogadro number of material. So, molar concentration, one can get is a number concentration if you multiply it by Avogadro number.

Then litter and meter cube there will be a factor of 1000. So, either you can represent this number per meter cube and number of ions per litter. So, if it is litter then you need not to multiply the factor of 1000. If it is meter cube, you have to multiply factor of 1000. That is the conversion factor between the litter and meter cube. And what is Z plus? Z plus is the valency of the positively charge ions; and what is n 0 plus? n 0 plus is the number concentration of positively charged ions; and what is Z minus? Z minus is the valency of the negatively charged ions; and n 0 minus is the number concentration of negatively charged ions. Now, if you are talking about a an electrolytic solution there.

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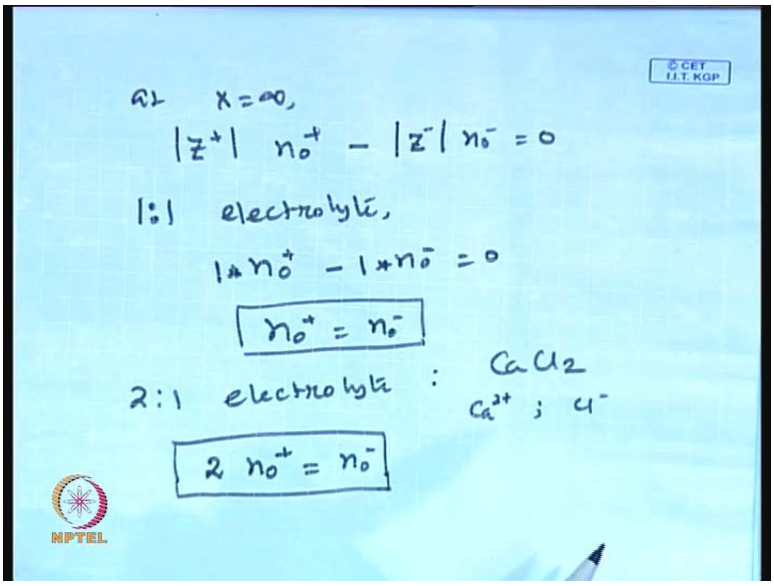

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at $X = \infty$,

$$|z^+|\, n_0^+ - |z^-|\, n_0^- = 0$$

1:1 electrolyte,

$$1 * n_0^+ - 1 * n_0^- = 0$$

$$\boxed{n_0^+ = n_0^-}$$

2:1 electrolyte : $CaCl_2$

Ca^{2+} ; Cl^-

$$\boxed{2\, n_0^+ = n_0^-}$$

Therefore, this equation can further be return can be request as at X tends to infinity mod of Z plus n 0 plus minus mod of Z minus n 0 minus is equal to 0. That means, if you are talking about Nacl solution 1 is to 1 electrolyte. 1 is to 1 electrolyte Z plus is 1; n 0 plus multiplied by n 0 plus minus Z minus; the mod value of z minus is 1; so minus of 1; so that means minus 1 is the valency; n 0 minus multiplied by n 0 minus will be equal to 0. That means, n 0 plus is equal to n 0 minus. So, number concentration of positively charged ions and negatively charged ions are equal at the bulk of the solution where the electro nucleate will be maintained. That means, total amount of positive charge will be equal to total amount of negative charge. If you talk about 2 is to 1 electrolyte for example, CaCl2. In CaCl2 that valency is C a plus plus 2 plus and chloride will be minus.

So, therefore, this will be Z plus will be nothing, but 2 n 0 plus will be equal to n 0 minus. This is the relation; this will be the relation between the the the number of number of concentration in the ions in the bulk. Similarly, you can go for the 3 is to 1 electron so and so forth. So, this simply means, the number of calcium ions will be number concentration will be less compare to the chloride ion and total electrolyte will be maintained if you have 2 is to 1 electrolyte. Now based on this fundamentals one can go for the potential distribution within the electric double layer, and one can find out the surface potential distribute the total potential distribution within the electric double layer and then, we can get an expression of relationship between the surface potential and number concentration through the movement of the ionic species; one is by the electric potential gradient; another is by the concentration gradient.

So, it is a diffuse diffusion, because the presence of concentration gradient and it is electrophoretic movement, because of the, because due to the presence of external electric field. At the steady state these two fluxes the ion flux, because of concentration difference and ion flux, because of the electric potential difference will be equal. That will be give you a clear cut expression of surface potential of the of the electric potential at any point of the electric double layer as a function of concentration of the electrolyte. That will see in the next class. Thank you very much.