Bio - Microelectromechanical systems

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Module No. # 01

Lecture No. # 06

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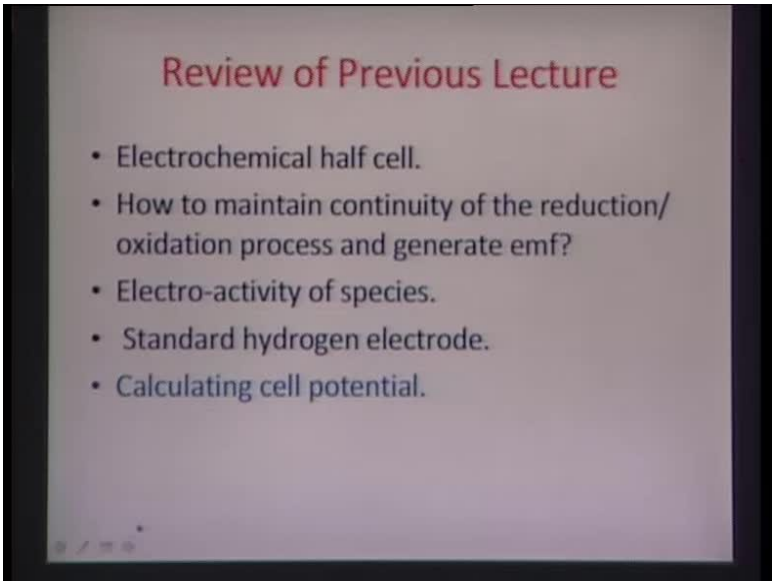

Welcome back to this 6th lecture on bio-microelectromechanical systems. I would like to review what we did last time. Last time we talked about electrochemical half cells and we also discussed about how to maintain continuity of the reduction/oxidation process. If you remember there was a lamp of zinc; if you put it in a copper sulfate solution; and immediately would be covered with metallic copper after which there would not be any reaction further. In order to maintain the continuity, we basically try to connect two half cells: one, where zinc was in zinc salt solution of zinc, and copper was independent; in another salt solution of copper, and then we connected both the solutions externally through a salt bridge and both the electrodes with conduit; basically that kind of was useful in maintaining a continuous flow of electrons and therefore generated an EMF and a current.

We also talked about electro-activity of species, basically the ability of a particular metal to displace hydrogen from water, steam or acid. Essentially, this is very important aspect of electro chemistry, because we kind of know an order in which what displaces what from its corresponding salt solution.

We also talked about relative absolute potentials and we discussed the standard hydrogen electrode, which is essentially a platinum electrode dipped in a 1 molar rescue solution in water; thus forming hydronium ions h3o plus, where hydrogen was bubbled through air at about 1 atmosphere pressure and the temperature was maintained about 25 degree Celsius or so.

So, then we started just about calculating cell potentials and there are the main question that needs to be addressed: this how can be really have an idea or relationship between the concentration of an analyte; and the EMF that it would generate and so for that we will be actually deriving something, which we have commonly known as the Nernst equation.

So, let me look through how this derivation is done; how would typically like to derive this through the fundamental principles of chemistry; and then go ahead with utilizing this Nernst equation to calculate the concentrations of different analytes of interest.

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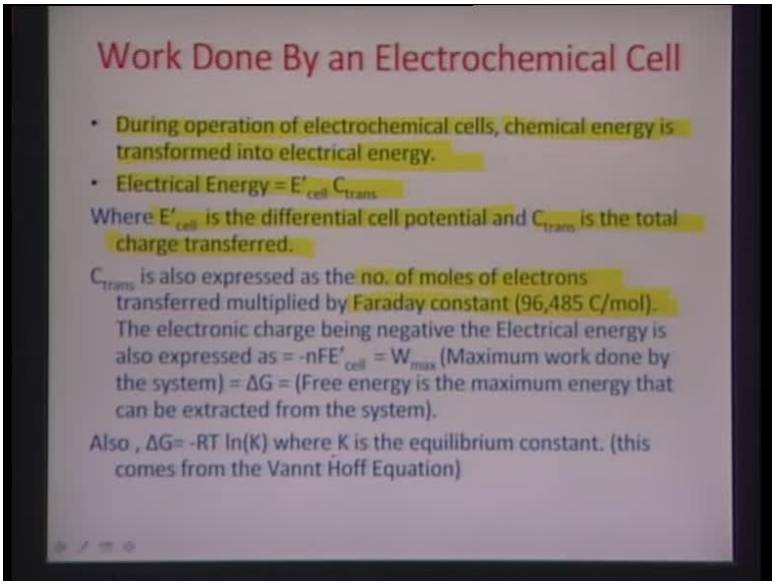

In order to start with, we really need to find out what is total work done by an electrochemical cell that we have discussed yesterday. So, as we know, there is a potential difference between the anode and the cathode. Anode is essentially where the oxidation reaction happens, for the cathode is where the reduction reaction happens and due to this potential difference an owing to this difference, there is a flow of charge across the circuit from the anode to the cathode. There is an electron flow and correspondingly there is a you can say that the conventional current direction is from the cathode to the anode.

So, there is work essentially which the cell does in order to transfer some electrons from 1 electrode to other and the amount of electrical energy that is essentially, spent during this operation of an electro chemical cell is I am sorry let me just go ahead and give me a minute.

Essentially, when we talk about work done from by an electrochemical cell, during this operation of charge transfer, the chemical energy we just stored in form of the salt solution with the particular metal is transformed into electrical energy. The total amount of electrical energy in this processes E dash cell into C trans, where C trans is the total charge that is transferred from 1 electrode to another; and E dash cell is the differential cell potential between both the electrodes.

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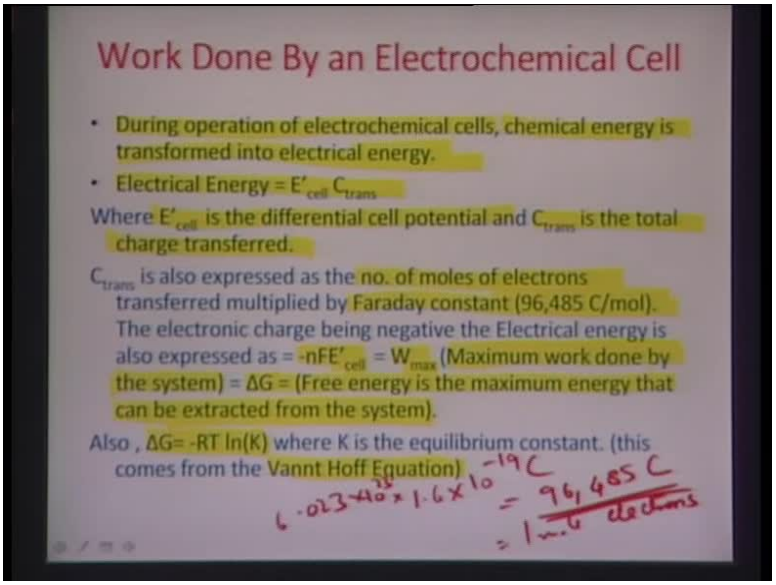

So, we can also express this in a different manner by assuming that n number of moles of electrons have really crossed from 1 electrode to another; and essentially, there is the famous Faraday constant, which is corresponding to the charge of 1 mole of electron. So, as we all know, that the electronic charge is around 1.6 into 10 to the power of minus 19 coulomb and if you multiply this with 1 mole the Avogadro number 6.023 10 to the power of 23 you get this - 96485 coulomb.

So, essentially, this value is the charge for 1 mole electrons. If you have n mole electrons, which I have crossing from 1 electrode to another, the C trans, which is the total amount of charge so crossed is also known as also given as n F and this is the negative charge. So, you have a negative sign which comes up.

So, this charge is transferred under potential E dash cell and that is essentially, what the maximum work done is of the system. This electrochemical cell essentially, in the process of a charge transfer of n F value under cell potential E dash cell makes or contributes maximum work given by minus nFE dash cell.

So, from the principles of thermodynamics, we also know this very famous Gibbs free energy concept, which is essentially the maximum energy that can be extracted from a system and that can be query to the maximum work done by the system. So, really in the Gibbs free energy; delta G, which is also given by this expression here - minus RT ln K and K is the equilibrium constant, which I am going to come in just about a little bit this is essentially this expression comes from the Vannt Hoff Equation.

We will just do this in a little bit, but what I am trying to say here is the delta G of any free cell or the free energy of any free cell is also equal to the maximum work that can be done by the free cells. So, delta G is minus nFE dash cell and is also can be represented as minus RT ln K.

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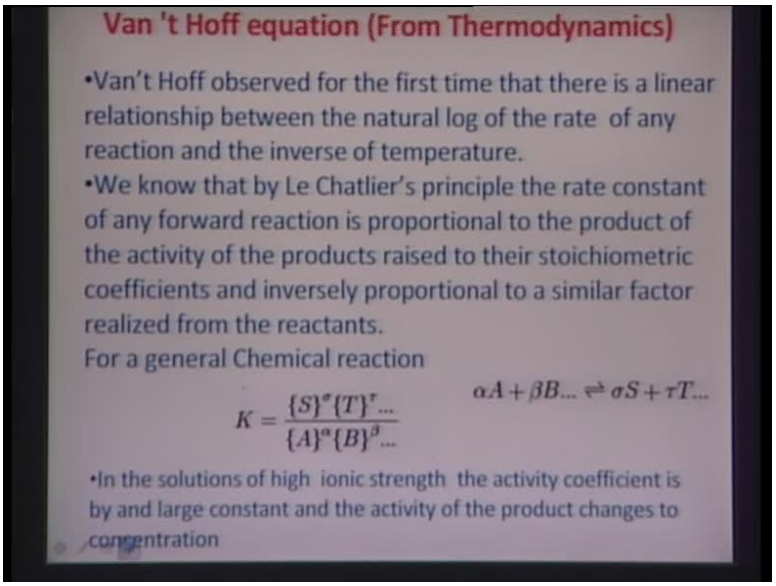

So, let us look at the Van't Hoff Equation and how it came from thermodynamics? So, the Van't Hoff for the first time observed that there is a linear relationship between the natural log of the rate of reaction and the inverse of temperature.

And the rate of reaction again assuming this to be the reaction - alpha moles of A, reacts with beta moles of B; and with several other components here, reversibly to obtain sigma moles of S, tau mole of T and several other products here -

So, by the Le Chatlier's principle you can really find out the rate constant of any such reaction. What the principle says is that the rate constant of any forward reaction is proportional to the product of the activity of the products raised to their stoichiometric coefficients. Stoichiometric coefficients here being alpha, as you see here in this beta, so how many moles are participating sigma and tau.

So, this is what the stoichiometric coefficients of these different reactions are and therefore, Le Chatlier's principle says, that the rate constant of any forward reaction is proportional to the product of the activity of the products raised to the stoichiometric coefficients.

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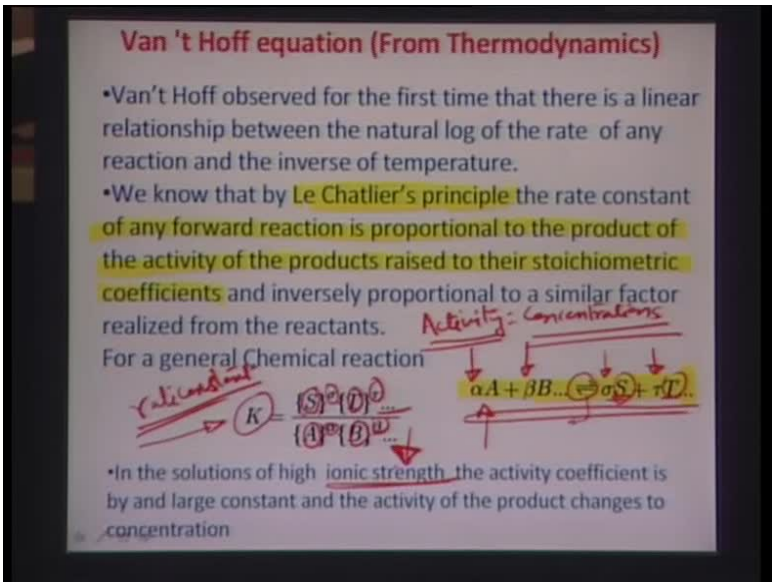

So here, I am just about to explain a little bit what activity really means. At this time, let us just consider to be equal to the concentration. Activity essentially is a term, which is a factor of the concentration of a particular analyte and I will be explaining this in a great details later, because for designing electrodes which would be able to do electrochemical sensing in bio memes devices. We need to find out sometimes the activity of an ion of interest; rather than the concentration of the ion of interest.

So, essentially by the Le Chatlier's principle, the rate constant of any forward reaction is proportional to the product of the activity of the products that means S and T, here of the products of the reaction and it is the multiplication of the product of the activity of S and T. That means the products of the reaction raised power stoichiometric coefficients, sigma and tau and the others and divided by the activity of the reactants of this particular reaction raised to power their stoichiometric coefficients which is alpha and beta.

For any general chemical reaction, this is how the equilibrium constant of the rate constant of a particular reaction can be found out. So, this is what is a critical parameter to study any redox reaction, reduction oxidation reaction and essentially the change in one like, let us say, the change in the reactant side would essentially lead to shift in the equilibrium, they would be an increase in the forward rate and so what would happen is that mole of A, would be converted into S or T and therefore, the equilibrium would shift back to it is normal, so any disturbance on any side in terms of concentrations of the

reactant of the product would lead to a shift of the equilibrium position and this equilibrium would try to get back to normal c that is how these redox couples really work.

So, in the solutions of high ionic strength, the activity coefficient is by and large constant and the activity of the product changes to the concentration. We really bothered about those situations, are the ionic strength may not be very huge and that is really the case in some of the samples of interest or the analytes of interest that we try to measure using bio memes architecture.

Because this ionic strength sometimes not under control and therefore, how do we really measure very accurately the EMF and correlate that to the concentration of an analyte, which has the low ionic strength is the challenge and for that there are certain rules and protocols, which are followed so that an in vitro sense. We can make a repeatable measurement and correlate the EMF of such a product of such reaction to the concentration one of the analytes of interest.

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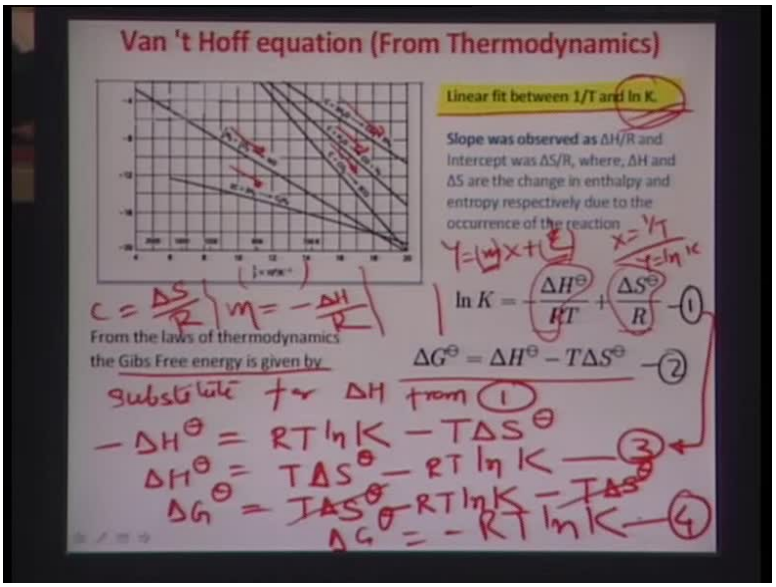

So, what essentially Van’t Hoff did is he plotted experimentally, the rate constants the natural log of the rate constant ln K, of some of these reactions in the gas phase typically with an inverse of temperature and what we found out that there is really a linear fit between the inverse of temperature and the natural log of the rate constant k as has been indicated by or as has been calculated from the Le Chatlier’s principle, so as there is the

linear fit you could express the 2 parameters here in question the x and y in the form y equal to m x plus C.

Question is what m and c would look like? So, from several experimental results what you obtained is that if you consider x to be 1 by t and y to be the natural log of the rate constant K; then, the slope m of in such a situation was also the minus change in or it was negative of the change in n enthalpy per unit. The red box constant R and the intercept C in such a case, in most of the cases was also the change in entropy of this particular reaction per unit the red box constant R. So, these are actually experimental results and in most of these cases, in all these different equilibrium situations of different reactants and products.

He obtained an uniquely similar kind of behavior, where he could find out or he could generalize that for these situation, the slope and the intercept are minus H by R read box constant and minus R and delta S the change in entropy of the reaction per unit the reduce box constant.

So, also from thermodynamics if we consider the Gibbs free energy given by relationship between the enthalpy and the total entropy of the system as delta H minus T delta S. So, if we substitute for H in this particular reaction, let us say we want to substitute for delta H from 1.

So, delta H would be also represented as RT ln K minus T delta S and delta H theta can be represented as T delta S theta minus RT ln K. So, let us say this equation is another representation of 1 that can be represented as 3.

If we put this 3, to find out what really the delta G value would form equation 2 and delta G theta can be represented as, T delta S theta minus RT ln K minus T delta S theta and essentially therefore, the delta G theta can be represented as minus RT ln K.

So, if we consider this to be equation number 4 and try to find out if there is a relationship between the nF E cell and this RT ln k from the Van’t Hoff equation, we get very simple relationship, which is the foundation for Nernst equation.

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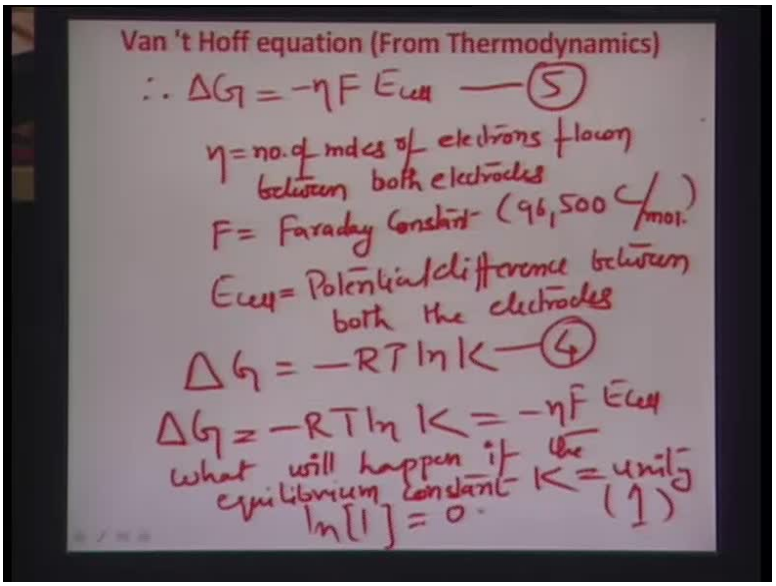

So essentially, we can say from we can write the equation 4 again here, simpler terms. So, the free energy delta G, which was also earlier, defined as minus nF E cell, where n is the number of moles of electrons flown between both electrodes; and F is the Faraday constant 96500 coulomb per mole charge of 1 mole electron; and E cell equals the potential difference between both the electrodes.

So essentially, delta G also can be expressed as minus RT ln K from the Van't Hoff equation. Remember equation number 4 therefore, delta G which is equal to minus RT ln K can be represented as - minus nF E cell. So, here is the little problem, because what will happen if the equilibrium constant k equals unity or 1.

Essentially, ln of 1 as we know 0 and therefore, there would not be any free energy of the system, which is available and this is major problem which one faces and therefore, we have to develop a strategy, where we can take care of this equation so that in the equation itself.

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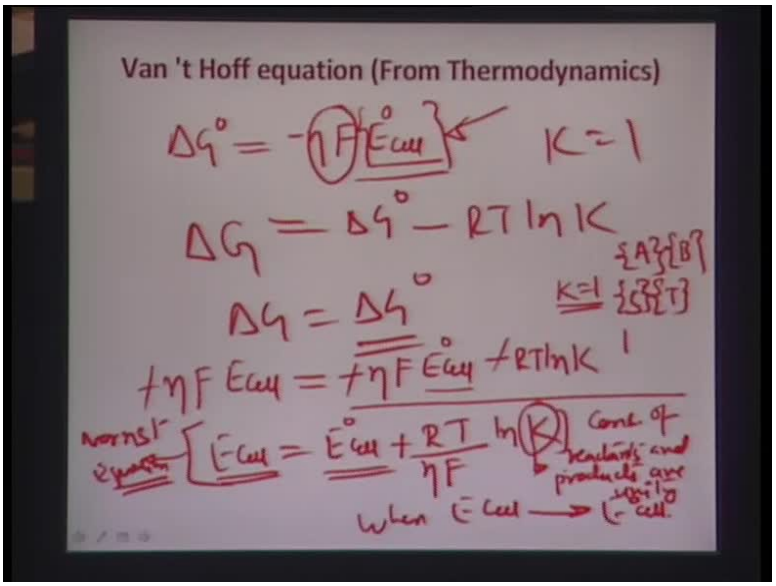

So, basically just this equation has to have scheme to common rate this problem that what happens, when the K value is unity and so basically what this equation can be modified as is that. Let us assume, that there is certain G value known as delta G 0, where in situations when the K value becomes unity.

And then, we assume that this corresponds to value of E 0 cell charge. Essentially, then this delta G equation gets modified to delta G 0 minus RT ln K. In this case, even if K is unity, the delta G value is equated to delta G 0. This delta G 0 can be converted or is can be thought of as the movement of nF charges across both the electrodes at potential difference E 0 cell and therefore, this is essentially the final form of what we call or what we know as the Nernst equation.

So, delta G is again n minus nF E cell from the earlier derivation; and it is equated to minus nF E naught cell that means the corresponding potential, when the reactants are all 1 molar in concentration, k mind you comes equal to 1 and one of the cases is that when all these different activities that we have been considering of A B S and T come out to be equal to all unity.

So essentially, the minus nF E cell can be equated to minus nF E naught cell minus RT ln K and this is what the final form of Nernst equation will look like, so we can calculate the E cell value by just looking at E naught cell and this term here RT by nF ln of K.

E naught cell again is the cell potential, when all the concentrations of so called reactant and products are unity, when E cell becomes E naught cell.

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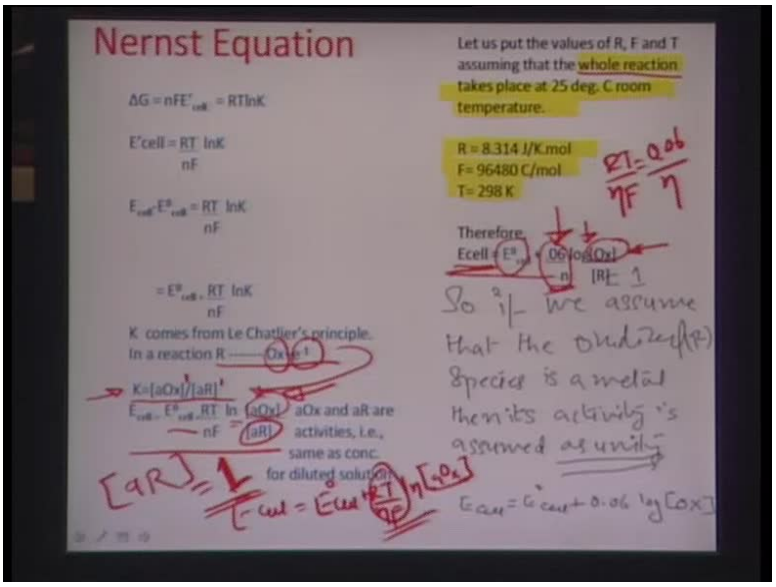

So, that is essentially what the Nernst equation is all about. Now, it is a very interesting thing that comes up that you can really equate the EMF the potential of such a system to the concentration of the reactants and products. That is again, what our goal is in all sensing that if analytes of interest and the concentrations of interest can be detected by looking at their EMF values of the particular cell.

So, let us do a little bit of post calculation on to this equation. There are 2 aspects, which I would like to mention here - one is that let us think that in a reaction certain reactant R is getting converted or oxidized into species Ox, again giving an electron.

So, in such a reaction, the rate of reaction can be written as the activity of Ox to the power stoichiometric coefficients, which is one in this case, divided by activity of R the material that is getting oxidized to the power of its own stoichiometric coefficient which is one in this case. So therefore, K can be written down as the activity Ox by activity R, in case of the EMF. If you look at the EMF E cell and Nernst equation, it comes out to be E 0 cell by this equation plus RT by nF natural log of K and K is activity of Ox by activity of R.

And essentially, when you are considering a case where there is a metal electrode and its corresponding salt solution, we can safely assume the activity of the metal as unity.

So, because it does not have its own ionic state in the solution in any case, it is fixed and it gives ions and those ions have a certain activity aOx. So, in that case, the Nernst equation would change to E cell equal to E 0 cell plus RT by nF ln aOx because the aR is unity in this case.

Let us also look at if we can do something about this RT by nF. If we assume, that the whole reaction takes place at room temperature and standard conditions 25 degree Celsius and if we take the value of R to be 8.314 joule per kelvin mole, the value of F Faraday constant to be 96480 Coulomb per mole, T act 25 degree Celsius means 298 Kelvin.

Therefore, we can calculate the RT by nF as 0.06 by n and therefore, in the Nernst slope of the E cell really comes out to be 0.06 by n. So, if you plot the E cell with the logarithm of the oxidant the concentration of the ion, which is also proportional to the concentration of the analyte of interest in some cases, where the analyte is getting oxidized.

Then, the E cell and the concentration are really in terms of a linear equation; and that is the beauty that slope of that equation is also inversely proportional to the number of moles of charge transfer that is taking place and n intercept of that equation is essentially these E 0 cell factor.

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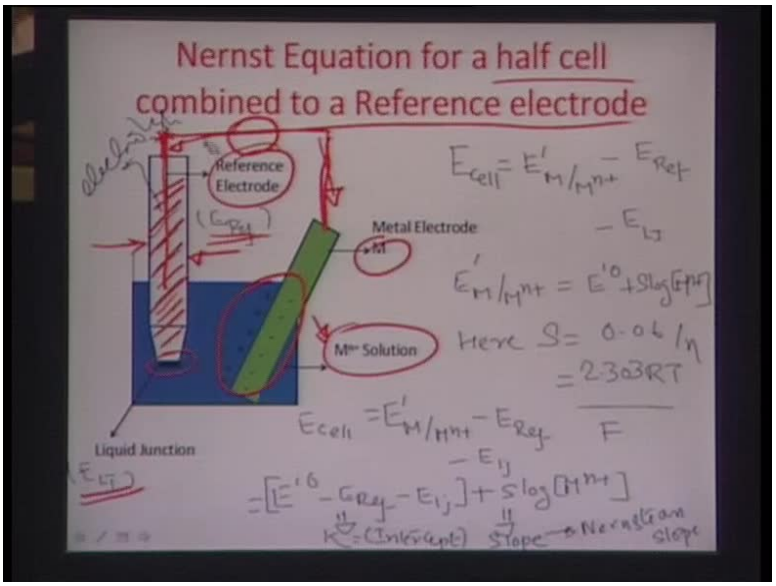

So, let us now look at some practical electrode design problems and from this essentially, we will move on to the corresponding memes modules of electrodes, which would essentially use the same principles of electro chemistry. But then, they will have to be considered once, because of their miniaturized size they have to be there; have to be other aspects like ionic strength or the concentration of the ion of interest or whether there any competing ions in that such a solution, which formulates major Faraday for designing such electrodes.

So, let us look at this half-cell combined to a reference electrode and let us just look at the drawing here first to begin with so, you have some kind of reference electrode with respect to, which you would like to measure the interaction between the metal getting into the solution as oxidized metal Mn plus.

The reference electrode here is essentially, nothing but a glass capillary which is covered by this liquid junction and this develops a potential. Let us assume, ELJ with respect to the solution and inside this last capillary we have this electro light, which is very standardized and it has a standard concentration and it has a sensing reference electrode here which goes into the electrolyte.

So, any charge transfer that is taking places through this liquid junction and through the electrolyte, which is inside the capillary and then goes on to this conjugate, this wire here as you can see and this is essentially formulates, an EMF here because of this

configuration and can be the reference electrode with respect to, which you measure the activity of a metal and a solution like this.

So, if we look at, if we really connect these two externally, let us say we are trying to measure by connecting these two externally using a voltmeter. So, let us say, we are just trying to connect these 2 electrodes externally using a voltage measuring device.

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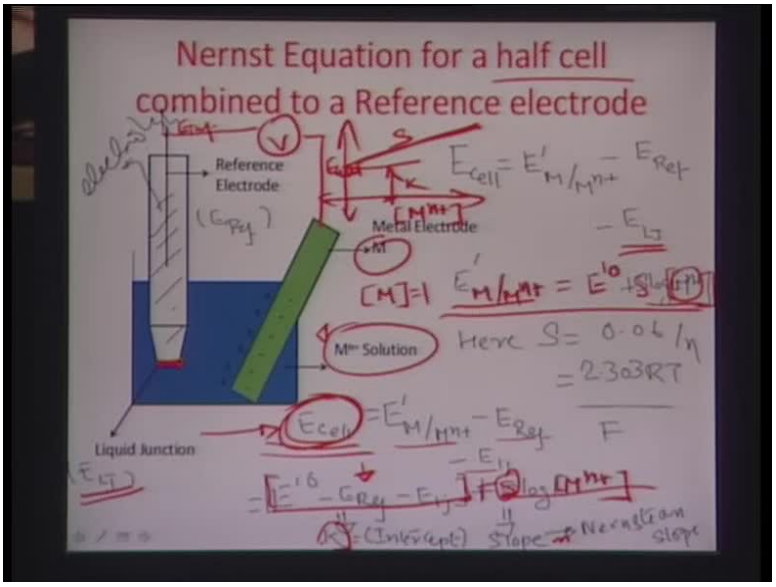

So, in that case, the E cell in this particular configuration can be written down as the E dash metal to metallic ion conversion M to Mn plus conversion. So, the potential of this interaction between metal and the metal solution or the salt solution of the metal minus; the E reference potential, which at this point E Ref minus again the liquid junction potential which is again contributing to the ion exchange process between the external solution and the internal solution.

And so from the Nernst equation as you know already, if we consider the activity of the metal here, to be equal to unity E dash cell in that case or E dash of this oxidation of the EMF produce by this oxidation reaction can be written down as the E 0 dash. This oxidation reaction corresponding to the case, when the reaction rate is unity or the rate constant K is unity, plus the Nernst n slope S 0.06 by n log of Mn plus the concentration of the oxidant.

Essentially, if the E cell can be represented as this particular value here, which is E dash 0 plus S log of Mn plus oxidant minus E reference minus ELJ, so we can actually pull this together and make this under the same bracket as E dash 0 minus E reference minus EIJ and plus S times of log concentration of Mn plus and this is essentially, a straight line.

So, if you plot the E cell value here let say, we plot it somewhere here with respect to the concentration of the oxidant Mn plus. You get a straight line from this particular equation y, which is E cell equal to Mx, M being the slope S plus C which is E dash 0 minus E reference minus IJ, assume this to be scale at suppose and this to be slope M. So, this here is really what this slope K is this intercept K is and the slope of the straight line is S therefore, again this EMF and concentration so is the strange linearity.

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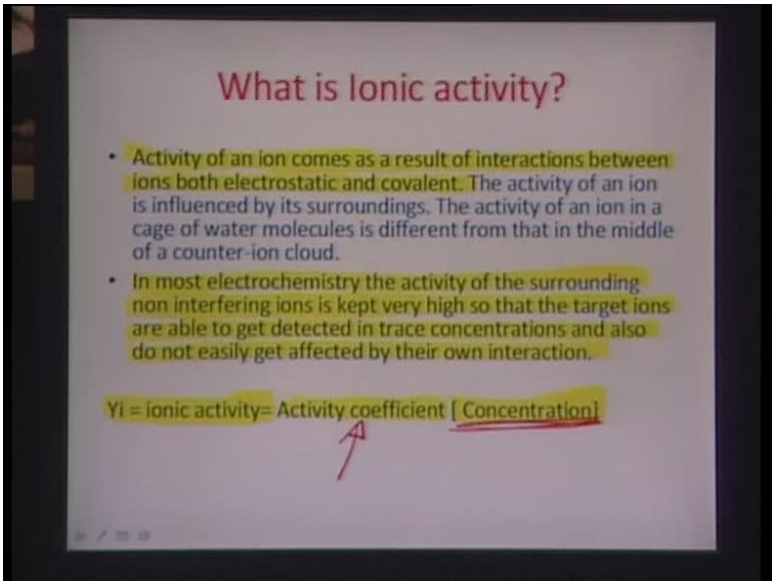

The next point, which I would like to emphasize, is that really if you look at the solution on very close bases there is a lot of other activity, which is going on inside the solution. The concentration of an ion is really very diffused, because there are so many other ion to ion attractions or interactions, which are happening that really can we say that the ion of interest that we are looking at has exactly the same effect in the charge transfer process as its concentration.

So therefore, it is pertinent to describe a term, which can give an idea of what happens when this small ion is interacting will several other competing ions there are forces of

attraction repulsion there is change in its overall state. There are so many counter ions, which are there in the solution. Let us say, we are detecting calcium plus 2 positive calcium ions. So, there are lot of let us say, chlorine ions around it, so there are these are counter ions, so there are ion clouds and there are this central ion of interest. So, the activity of an ion is the corresponding factor, the corresponding term, which can give an idea of the interactions between ions both electro static and covalent.

So, the ionic activity can be defined as of an often ion can be defined as, the result of the interactions between ions both electro static and covalent. The activity of an ion is influenced by its surroundings. So, if suppose the ion in a cage of water molecules it may have a different activity factor then, when it is in the middle of the counter ion cloud.

And in most electrochemistry the activity of the surrounding non interfering ions is kept very high, so that the target ions are able to get detected in trace concentration and also do not easily get affected by their own interactions. So, this is something very critical to be observed that insertions where you have several competing ions the best way to reduce the interaction between these competing ions that is to create the high ionic background.

And essentially, you create something some ions or something which is having an ionic state, but it is non-interfering with ions of interest. If such a kind of a situation happens, then you can by and large create a huge background. So these interactions between the competing ions become very smaller insignificant.

In that case, the ionic activity, which is the more appropriate term giving an idea of the electronic interactions can be described as the activity coefficient and this is the constant terms the concentration of the particular ion of interest.

Now, this activity coefficient can be depending on different situations, it can have different values we are sometimes the ionic activity can be too high, sometimes it can be too low and if the idea is there if you have a surrounding non interfering heavy ion cloud around the target ion.

It kind of gets equal to the concentration of the ion and you can easily get to detect the exact quantity of the target ion of interest. So, therefore especially in memes kind of protocols, where we talking about selecting over a very small volume of liquid.

There is almost always a tendency of the activity to be very much different the concentration. So, we are next going to find out, how it is possible by designing an electrode to pick up a certain ion over let say several competing ions and that is how, we get into the field of ions selective electrode.

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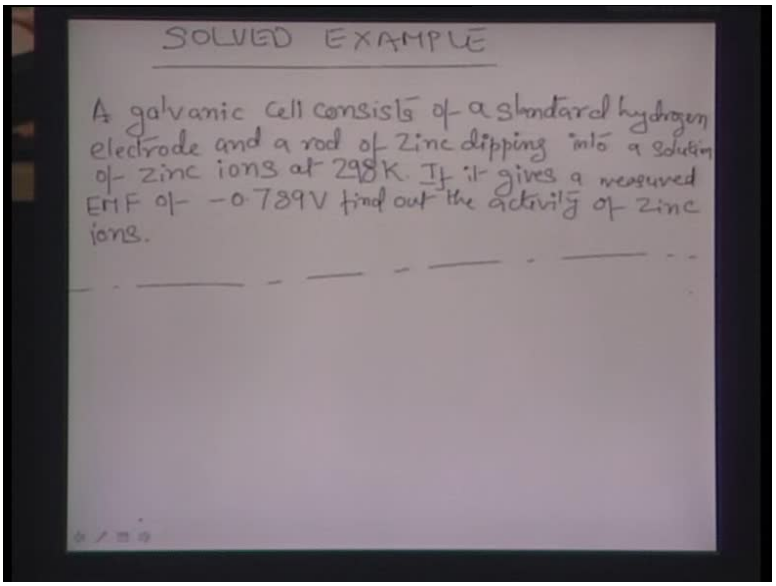

So basically, let us do a little bit small problem on finding out the EMF before going into the ion selective electrodes. So in this example, there is galvanic cell, which consists of a standard hydrogen electrode and a rod of zinc dipping into a solution of zinc ions at 298 Kelvin. If it gives a measured EMF of minus 0.789 volts find out the activity of the zinc ions.

We apply the Nernst equation here and essentially, the E cell in this case can be represented as the E 0 cell plus the Nernst n slope 0.06 divided by n; n in this case, because it is the zinc getting oxidized into Zn plus 2 and 2 electrons, the n equals actually 2 in this case and into log of the activity of zinc plus 2 ions.

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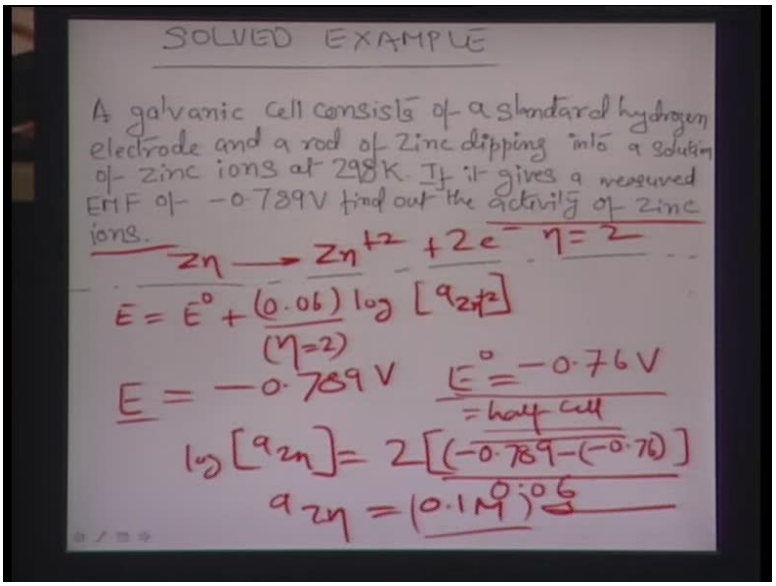

So, it is written I mean or it is given in the problem that the EMF E of this particular cell is minus 0.789 volt and it this is with respect to a standard hydrogen electron. So, the E 0 the standard potential with respect to that electrode from the tables, which I have described in my earlier lecture, comes out to be 0.76 volts.

So, this is essentially the half-cell potential, if you remember we had discussed a table, where in all these half-cell potentials where found out by connecting the respective cell to a standard hydrogen electrode. So, from this equation therefore, substituting the values of E and E 0 and n equal to 2, we obtain the log of the activity of Zn as 2 times of minus 0.789 minus of minus 0.76 divided by 0.06.

The activity of zinc comes out to be equal to 0.1 molar. So, the activity of the zinc ions in this particular example is around 0.1 molar, it may happen the concentration of the zinc ion is the little more but due to the shielding effect the activity may be a little less.

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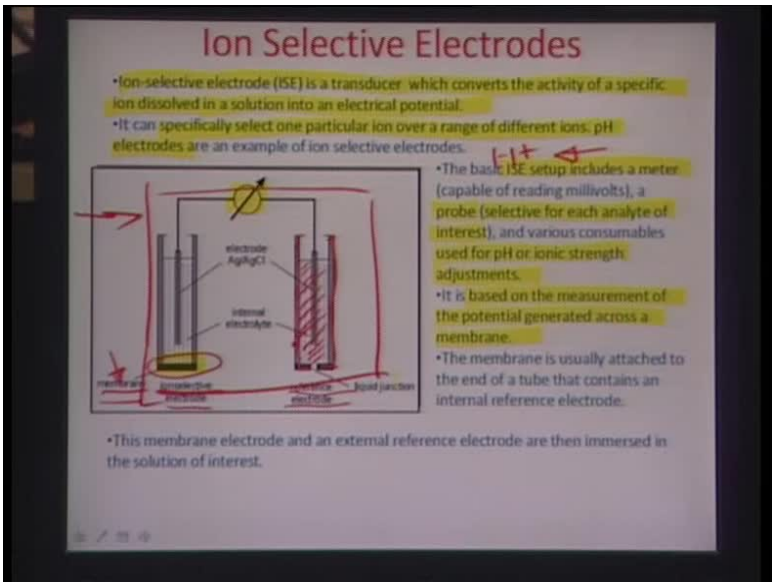

So now, let us look at what these ions selective electrodes are or what they do? So, we are very often faced with the problem of detection, where there are more than one competing ions in a particular solution; and in that case we want to find out a particular ion in an analyte of interest.

So essentially, the ion selective electrode is a transducer, which converts the activity of a specific ion of interest dissolved in a solution into an electrical potential. So, even though there are more than one such ion in the solution and the ion of interest has to be specifically reported using an ion selective electrode.

So, the basic set of an ion selective electrode can be represented here, in this particular figure and if you look at the setup you can see that there are 2 electrodes. One is the reference electrode, which is made in a similar manner with a capillary and essentially a liquid junction, like any reference electrode would make and an electrode immerse inside a solution of standard or known concentration of ions.

The ion selective electrode essentially is kind of copy of the same with an exception that instead of the liquid junction have the membrane here, which selective to an ion of interest. Therefore, this membrane is designed in a manner there it can take up only a few ions of interest from the solution, which this membrane is design to take up and therefore, this whole assembly is immerse inside the analyte of interest and the potential

of is found out the potential difference is found out between the reference and the ion selective electrode.

Therefore, we can say that it can specifically the job of it is to specifically select one particular ion over a range of different ions, so for examples are pH electrodes and just picking up hydrogen ions. So, the pH electrode picks up only hydrogen ions and leaves the other ones behind therefore, that is an ion selective electrode.

So, the basic ISE setup includes meter a probe selective to each analyte and the section is done by using this small membrane here and essentially, it also uses various consumables used for pH or ionic strength adjustments.

This is important, because you want to create a large background of ions so that you can pick up an ion of interest in that background. So, the interaction of that particular ion of interest with the other ion surrounding at are eliminated by the strong interaction forces offered by the background in general.

But again as background ions are non-interfering in nature, they would really not contribute to any charge transfer process or only charge transfer would come due to the particular ion of interest.

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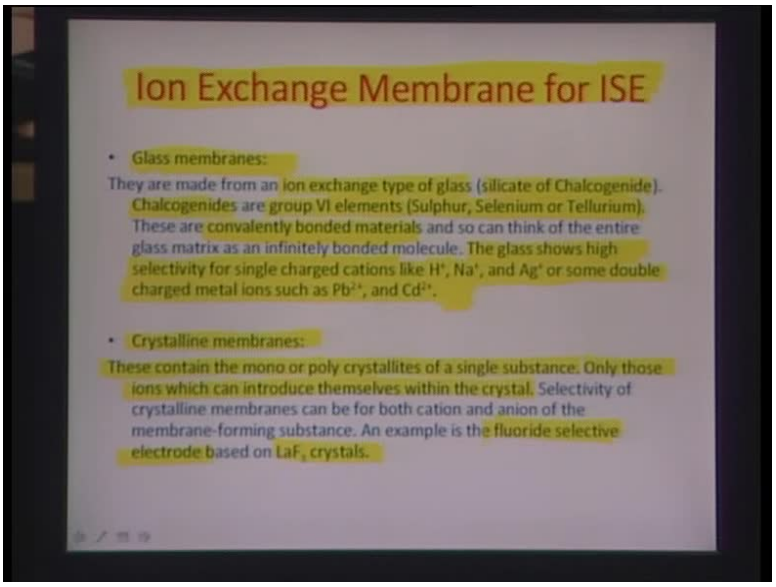

So, an ion selective electrode essentially is based on the measurement of the potential generated across a membrane here, a selective membrane here, membrane is usually

attached to the end of this tube and essentially, there is the solution here for internal reference of this particular electrode and the whole assembly is immersed into the analyte for the measurement purpose.

Let us talk a little bit more about, what these membranes are or what they are supposed to do? So, the basic property that is imparted on to the ion selective electrode is by virtue of the membrane. So, the membrane should have some characteristic of some feature, may be if it is a network of force, which might match to a certain ion size, it might be able to pick up a certain ion over the n number of other competing an interfering ions so there is a size based selection in that case.

It could also be made up of some biological material, which can recognize only a certain ion or a certain group of ions of interest. Essentially, there are several different kind of ion exchange membranes; there are available for designing ion selective electrodes.

Let us look at these one by one. So, there are these Glassy membranes, which are made from an ion exchange type of glass and they are typically the silicates of Chalcogenide metals, Chalcogenide if you just recall from the group VI of the periodic table are Sulfur, Selenium or Tellurium. These are also known as the Chalcogenide or the group VI elements of the periodic table.

So essentially, the silicates of such metals form excellent ion exchange type of glassy materials. So, they are covalently bonded materials so you can think of the entire glass matrix as an infinitely bonded molecule. It is one bonded molecule with in between spurs these sulfur, selenium, tellurium these kind of metals.

So, such classes have the tendency by may be the virtue of their crystal structures to show high selectivity for single charged cations, so ions like let us say, hydrogen plus sodium Na plus silver or some at the most some double charged metal ion such as, let say lead and cadmium ions, so these glasses show at strange tendency of just adhering to certain size with single charge in a certain size with double charge. So, that is why, it is probably related something to do with a crystal structure of these covalently bonded silicates of Chalcogenide.

The other type of ion exchange membranes are crystalline membranes and one example that I can code is the lanthanum fluoride, crystal for florin ions, so essentially, this is the

size based selection again. So, these contain mono or poly crystallites of single substances. Only those ions, which can introduce themselves within the crystal, are selected by virtue of membrane being formed by this crystalline material.

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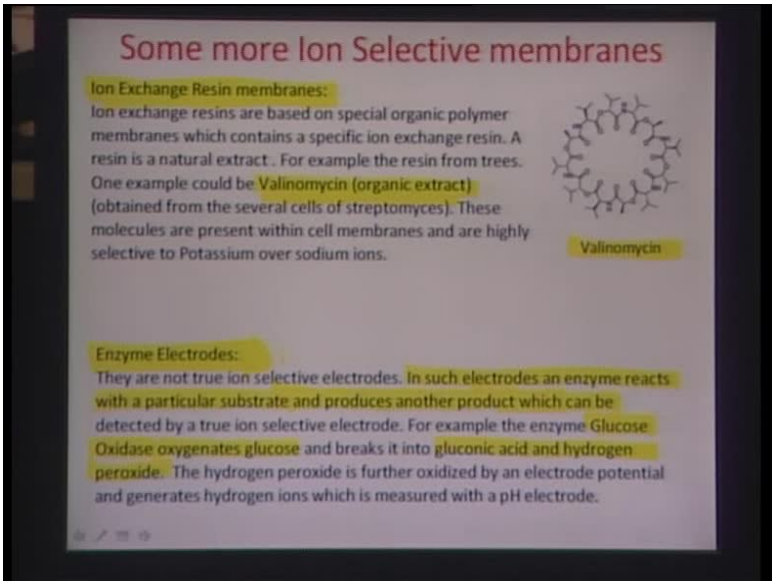

So, these are some of the various types of ion exchange membranes that are available, so more would be this ion exchange resin membrane. These are very interesting nature, so there is a compound call Valinomycin, which is normally available in the cell membranes of Streptomyces. Essentially, the purpose of such a compound is to give way to exocytosis processers of exchange of potassium and calcium ions between the periplasm and the cytoplasm of certain cell.

So therefore, if such kind of materials can be again enclosed and entrapped in inside a polymeric material or polymeric resin it can form an excellent source of selection. Let say, potassium or calcium just as it happens naturally, in case of cell by virtue of opening and closing fine channels inside the artificial membrane that you make using these.

So, the whole idea here is that Valinomycin, which is also an organic extract. Specially, it is a natural extract you can say, can be used for the same application that it is used for naturally and this can be a fantastic ion selective electrode.

Another type of ion exchange membrane is really enzyme electrodes although, these are really more related to the overall selectivity of an analyte of interest.

So, what happens that in such an electrode, there is an enzyme which would react only a particular substrate. So, the whole purpose of sensing or detection is to detect one particular species over the other competing species. So, in this case the particular enzyme may just react to the species of interest say for example, in Glucoses I have mentioned earlier quite number of times.

This Glucose oxidase enzyme would oxygenates glucose and breaks it into gluconic acid and hydrogen peroxide and therefore, this is again giving a selectivity aspect to the sensing mechanism.

Hydrogen peroxide can be measured by a pH electrode of force, which has some other ion selective membrane which can, may be some Glass of Chalcogenide which can easily take up the hydrogen plus ions over the other competing ion.

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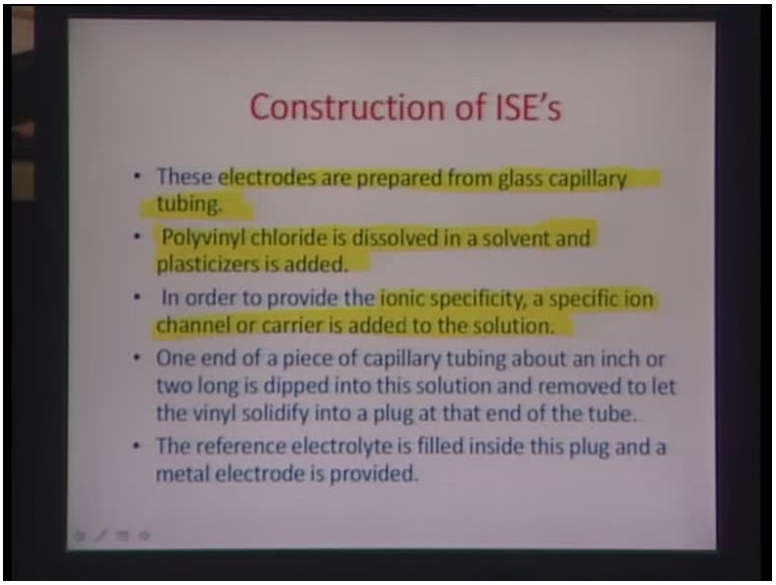

So, there in Nernst cell what the ion elective electrodes are how they are constructed. So essentially, the electrodes are prepared from a glass capillary tubing and resin material most of these is polyvinyl chloride PVC, which is dissolved in solvent; and added with some plasticizers just like to recall that plasticizers give this unique ability of the polymer to flow more by getting into the chains of a polymer and make the chains role over more easily. So, you add some plasticizers for making it more fluidic nature specially, when they are in the liquid form before the cure.

And therefore, this particular ions specific material whatever you have to design is added to this particular solution and then this capillary is dipped into the solution and solution gets into the end and forms the small plug and plug is provided certain ion certain strength ionic strength of particular solution is put into the glass capillary. Therefore, you have this capillary the solution insided, conduit which is coming out and then the end which is the plug with may be polyvinyl chloride, polymeric resin with ion exchange material trapped inside it. So, this can give all properties of what and ion selective electrode would essentially need.

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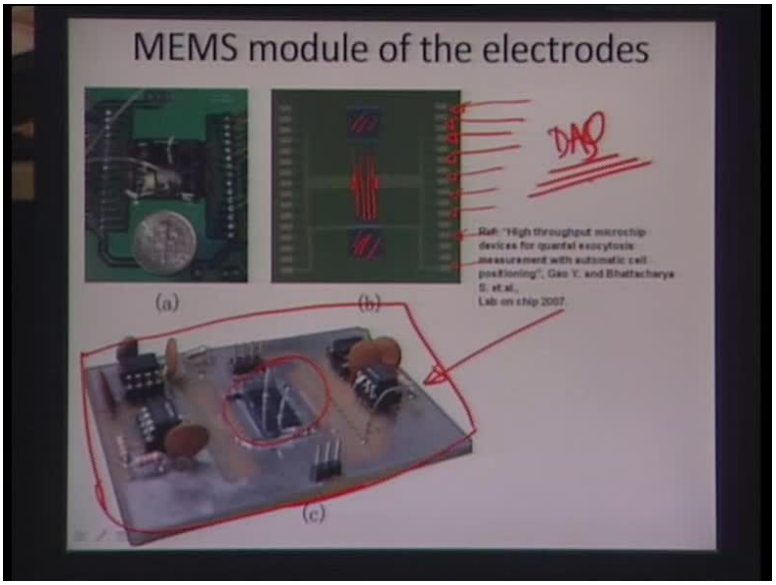

The reference electrolyte, which is filled inside can vary depending on what analyte of interest is being measured using this particular electrode. So, when we talk about the various memes modules for electrodes, the basic idea in memes is that whatever is being done by the conduit can be transferred on to a microchip level and some of these electrodes essentially, can be screen printed on to these chips; rather than hanging plane wires. For example, if you look at this particular chip here and this again an excerpt from lab on chip is a paper reported in a lab on a chip for a measurement of exocytosis processors in single cells essentially; and this is also an excerpt of work that had been earlier done in our group.

If you see here, these are screen printed electrodes on a silicon wafer, which can be easily fabricated using this micro fabrication strategy is that we have been talking before

and there are these, this small positioning channels this narrow small positioning channels between these sensing electrodes and 2 reservoirs essentially on both sides here.

There is the flow of cells and positioning of cells over these individual channels or electrodes and the ion exchange resin here, can be coated spin coated selectively using photolithography on certain specific areas, where these electrodes interact with solution of interest and can be rapidly recorded using a DAC system, data accusation system and so all the electronics can be built; surrounding the particular chip here of interest and this can be a bio memes device to measure electrochemistry of a cell single cell.

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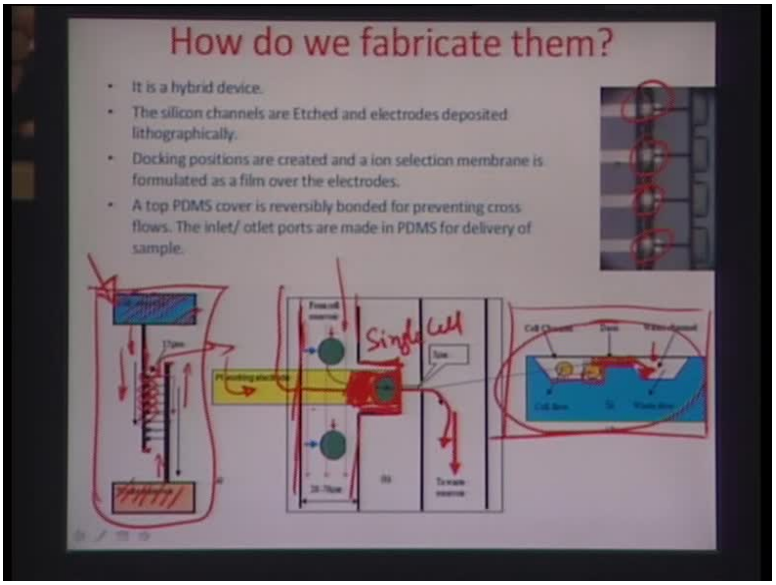

So, how do you fabricate some of the devices to make the positioning of the cell? Is very interesting that you basically, make the channel here in this particular form in a silicon in a manner that is shown like this-

So, this essentially is the top elevation of the device, so you have cell reservoir on one side, these are all microscopic features and you have transportation channel which is blocked here at this particular end.

So, this channel is blocked in one end; and imitating out of this cell reservoir and there are these docking stations this small 15 microns by 15 micron docking stations and silicon, which can dock a cell like this and following this there is small channel, very

small channel, which is lower than the size of the cell but can essentially, flow the fluid which is carrying or transporting cell to this docking station.

So, if you look at this whole I say, on the side view this is essentially, where the cell would go and dock and this is the small dam, which is able to connect both sides that mean side 1 and side 2 on this device so this is the waste channel side.

The waste channel side similarly positioned. So, if you see at the waste side, you find out that the waste side also has the channel emanating from this waste reservoir and it goes on stops and get blocked all the way here and there are connecting channels in between the main flow channel and the waste channel in this particular manner.

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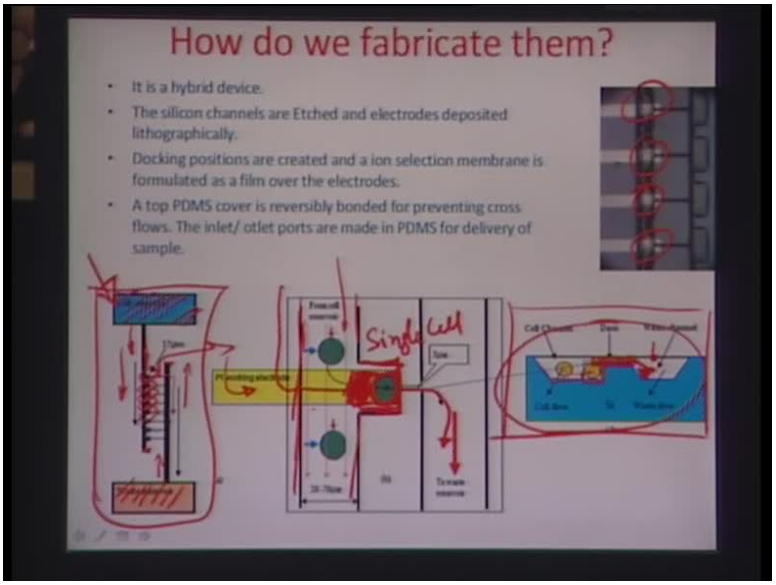

So, the cell comes here docks itself and the solution, which carries the cell, is able to move from this particular dam area into the waste area. That way the fluidics is made continuous the fluid flow is made continuous, so the fluid comes like this goes into this area because it cannot go ahead anymore, because it has a blocking here, there is a certain pressure here and if comes in positions the cell and moves out into the waste reservoir something like this but then, we can actually the docking station of the size of a single cell.

So therefore, if it is 15 by 15 microns and we assumed the diameter of this particular millions cell to be about 15 microns, this is what happens you have these cells here, kind

of dock in this docking stations and the electrodes the platinum working electrodes are placed just about the docking position. Here, you can give the ion exchange resin in form of a coating. So, whatever happens to the cell and whatever leases happens cell through it fine channels can be easily gazed using this platinum electrodes through this ion exchange coating which can be given on the membrane, which can be given on the top of the electrode here.

So, this is fantastic example of how an electro chemical device can be fabricated from memes platform to more towards memes platform. Thank you.