Bio-electrochemistry

Prof. Mainak Das
Department of Biological Sciences & Bioengineering & Design Programme
Indian Institute of Technology, Kanpur

Lecture – 04
Galvanic Cells-I

Welcome back to the lecture series in Bio-electrochemistry. So, we have finished first 3 lectures and we have talked about the basics of current and measurement of current voltage, free energy change, work done power and the Ohm's law. And we have derived all the basic relations and those basic relations will come very handy as we will progress.

So, as this is a 4 weeks course. So, initially I will be going at a very slower pace purposefully, maybe the first week content may spill over a little bit to the second week, but do not worry about it because what I personally believe is if your fundamentals and basics are clear and once you get it cleared once and for all then you will be much more well equipped to handle any kind of problems under any kind of situations in the scientific endeavor.

So, today what we will be doing will be talking about the very basics what you must have studied in class 11 and 12 about galvanic cells sometimes called Daniell cell also. So, today's lecture we will be about the galvanic cells where you must all have heard about copper electrode, zinc electrode, cadmium electrode, silver electrode. There are series of those electrodes are being used and you have heard about that you know from one electrode the current flows from to the other electrode likewise and so forth. There are so many and you have heard how the cells are being represented you have talked about half cells and everything. So, today we will revisit those basic fundamental concepts, in simpler terms what does that mean and in the light of what we have studied in last 3 lectures.

So, to start off with in the last 3 lecture one thing which I have highlighted every point is, say for example, there is a flow of energy or flow of current or movement of charge from one point to another. So, what are the possibilities? Either it will be a spontaneous flow where the free energy change will be negative delta G negative or it will be energy intensive process where you have to give energy in order to make that reaction happen which would be delta G positive.

Now, we will take a practical situation where we will talk about two metals where the charge is flowing between them in the presence of a medium which would be an electrolyte and the presence of a barrier which will allow only the small molecules to pass nor the big molecules will come to that.

So, essentially a galvanic cell or a Daniell cell what we will be discussing today is a practical situation of what I used to represent in the first 3 lecture from point A to point B like when so and so forth you must have seen it several times. So, today we will talk about a real life situation where there is a real metal along with its corresponding salt solution another metal along with his corresponding salt solution and how do they interact, how based on their work function the energy flows in one direction and could we reverse the process. So, what we mean by reverse the process?

We must have heard about all of you we have heard about rechargeable cells, we always say could it recharge this cell. In other words say for example, before I get into the technical details try to understand say for example, there is a metal A and a metal B. Now, I am replacing at two objects now we know that the current flows from metal A to metal B. What could happen? Say for example, A has hypothetically think of a situation A has a higher power to lose an electron in other word with respect to B the metal B A can lose electron faster, so if A could lose electron faster with respect to B; that means, with respect to A B can accept electron faster. So, in other word the oxidation potential of A is higher. So, A can get oxidized and much more faster than B.

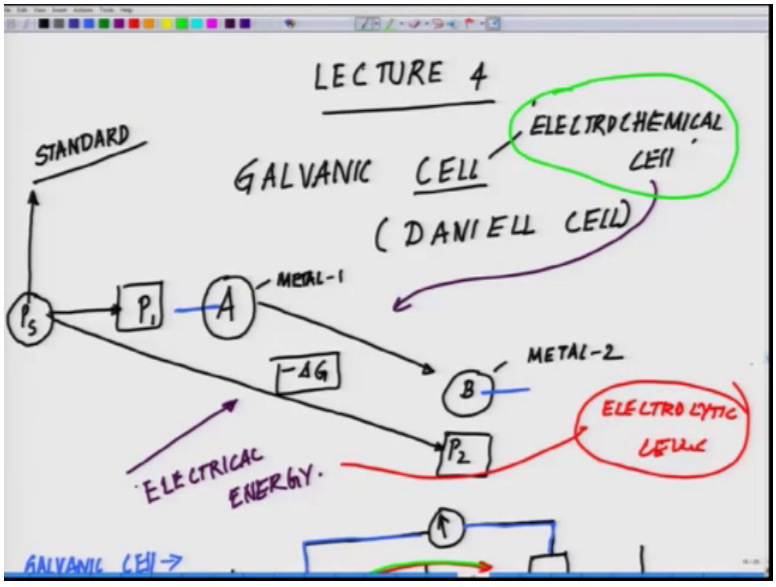
In other word B can get reduced faster than A, is a vice versa we can accept electron faster you can donate electron faster. And now say for example, A has donated electron somewhere other we are not even bothered about it and B is accepting an electron. So, here is a process where there is a movement of electrons which is happening and such movement is associated with certain currents and why there is a moment, what made us and how we calculate these kind of things like you know, why that metal a will be at a higher oxidation potential as compared to B or if we talk about the reduction scale why B will be at a higher reduction potential as compared to A, how we compare them?

So, we needed a way to compare all these things with respect to something. When we say 1 kilogram or 10 kilogram, so there is some comparison with respect to this or we say 1 nanometer or 1 meter. So, there is a comparison. So, somewhere out there in on earth we

have set like this distance we call as 1 meter or 1 nanometer based on that you can set a nano meter or whatever you know. Similarly for telling that this has a higher oxidation potential to the other one we have to have something which is a baseline, with respect to the baseline we start calculating.

So, we will be talking about that baseline value which is the standard electrode potential or standard electrode. So, say for example, now to a start off with just give you an idea about how this works.

(Refer Slide Time: 06:51)

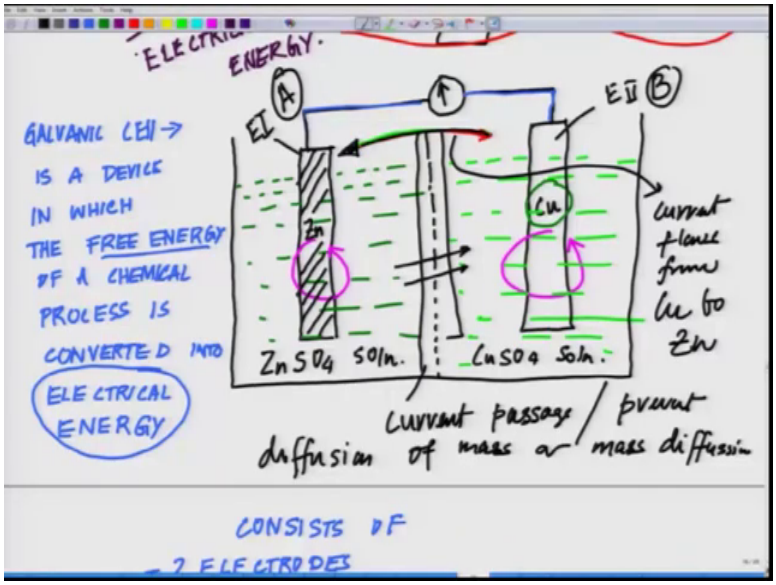


Lecture 4. So, today our topic is in galvanic cell which is sometimes also called Daniell cell, you may come across this word. So, do not get perturbed when you see this word Daniell cell. And this is not biological their cell this is the electrochemical cell, electro chemical cell.

So, when we talk about there is a flow of current from A to B right. So, this assuming that delta G is negative delta G, it is a spontaneous process. Now, this will happen when A is sitting at a particular say potential P 1 and B sitting at potential P 2. Now, how we calculated this potential with respect to what there has to be some something with respect to what we calculated these potentials in other word we needed a standard. So, that is our P standard, with respect to P standard we call it P 1 and with respect to P standard we call it P 2. So, this is that standard we are talking about P 1, here we have P 2.

Now, calculating this standard or what we considered as a standard. What will be dealing in the standard? Electrode potential, we will come later into that. Now, what we decided we considered this as metal 1 and this one as metal 2. So, there are two metals or where we are calculating it. So, let us take a practical example of a cell electrochemical cell which is made up of zinc and copper.

(Refer Slide Time: 09:22)

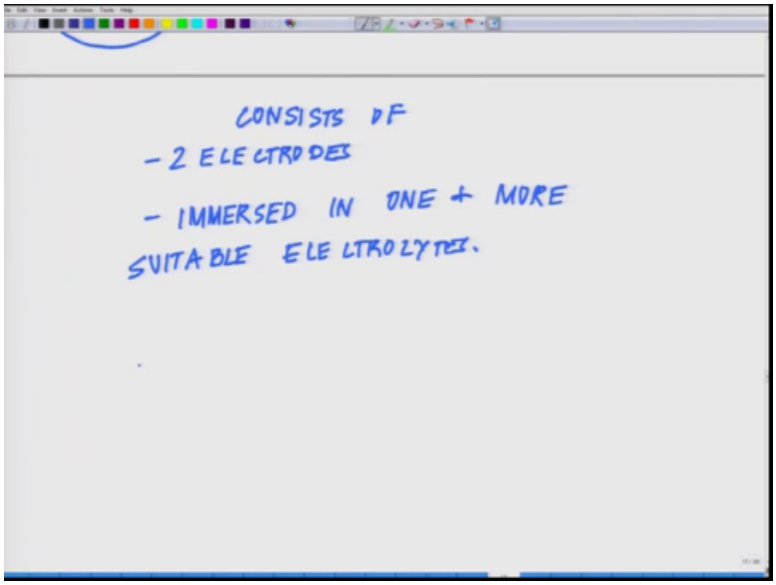


So, let me make this cell it is something like this. Think of a big beaker and which is separated by a porous membrane like this semipermeable porous membrane which selectively allows very small molecules to pass through it you have a zinc electrode. You can keep on replacing it zinc electrode you have a copper electrode and here you have an ammeter which is connected to it and this is solid zinc rod out here, similarly a copper rod and this is in zinc sulphide, sulphate solution Zn SO 4 in solution. So, again similarly this is in copper sulphate solution.

So, galvanic cell if we talk about a definition of a galvanic cell. So, this is the, I will come back to that figure in a second I can write here. So, a galvanic cell is essentially is a device in which the free energy of a chemical process, free energy of a chemical process is converted into electrical energy, into electrical energy. In other word here is a situation where, so they are sitting at different energy level metal A metal B and the free energy change now correlate this the free energy change of a chemical process. So, there is a chemical process from A to B is converted into electrical energy.

So, this is what a cell talks about. Usually now talking about the details of it, usually such a cell consists of 2 electrodes.

(Refer Slide Time: 12:17)

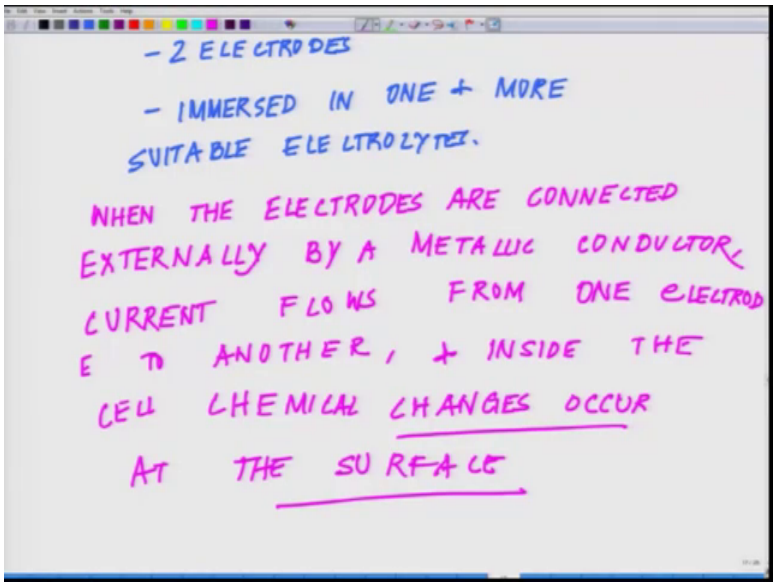


Requirements are 2 electrodes and these 2 electrodes consists of and they are immersed is one or more suitable electrolytes, immersed in one and more will realize why one and more at this point we are talking about two different electrolytes, the one or more suitable electrolytes. When the electrodes are connected externally by a metallic conductor, this is a situation when electrode is connected. So, this is the metallic conductor we are talking about and here we are having the different salt solution that is zinc sulfate and on the other side we are having copper sulphate.

When the electrodes are connected externally by the metallic electrode current flows from one electrode to another, there is a flow of current across this which is denoted by right, so there is a flow of current. So, we will talk about the directionality later current flows from one electrode to another and inside the cell chemical changes occur at the surface of the electrode.

So, what is happening? That is a second thing which is happening on this surface there are chemical reactions which are happening.

(Refer Slide Time: 14:19)



To summarize this two important things when the electrodes are connected externally, when the electrodes are connected externally and they connected when the electrodes are connected externally by metallic conductor current flows from one electrode to another, from one electrode to another and inside in the cell chemical changes occur at the surface of the electrode.

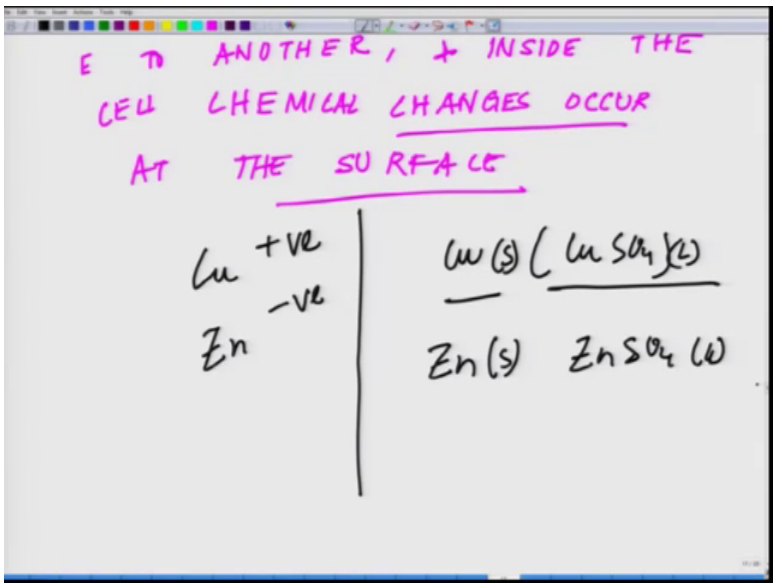
So, now what are the chemical changes which are occurring at the surface of the electrode? This part is important what will be dealing with. So, a galvanic cell is also rightly called electrochemical cells whereas, an electrolytic cell is the one in which electrical energy from the external source is used to carry out a chemical change. So, in other word if we call this as electrochemical cell if we are calling this one as electrochemical cell, now if we have to put electrical energy for this reaction to happen say reverse reaction we have to give electrical energy then those kinds of cells are called electrolytic cells.

So, these are the two terms you remember electro lytic cells. So, on one hand we are talking about electrochemical cell, the other hand we are talking about electro light excel. Now in a Daniell cell a zinc rod is immersed if you look at it in a Daniell cell. So, here you have a zinc rod which is immersed in Zn. So, 4 solution and a copper rod you see a copper rod here which is immersed in the copper sulphate solution. The two solutions are kept separated by a porous barrier. So, here you are having this whole porous barrier. The

barrier allows current to pass through it. So, it will allow the current to pass through it, but prevent the mass diffusion, but prevent diffusion of mass or you can call it mass diffusion.

So, it is kind of a does not allow these huge salts to move through it zinc and copper are 2 electrodes. So, here you have the electrode 1, here you have electrode 2 and if you look at electrode 2 you can name this as A to B which, so ever way you like to place them when these are connected externally by a metallic wire current flows from copper to zinc. So, essentially the car in case of current, so here we are giving the directionality current is flowing copper and why is it so, we will talk about it current flows from copper to zinc through the wear ok. Copper is said to be positive and zinc is said to be negative. Copper is considered as positive and zinc is considered as negative; why is it so.

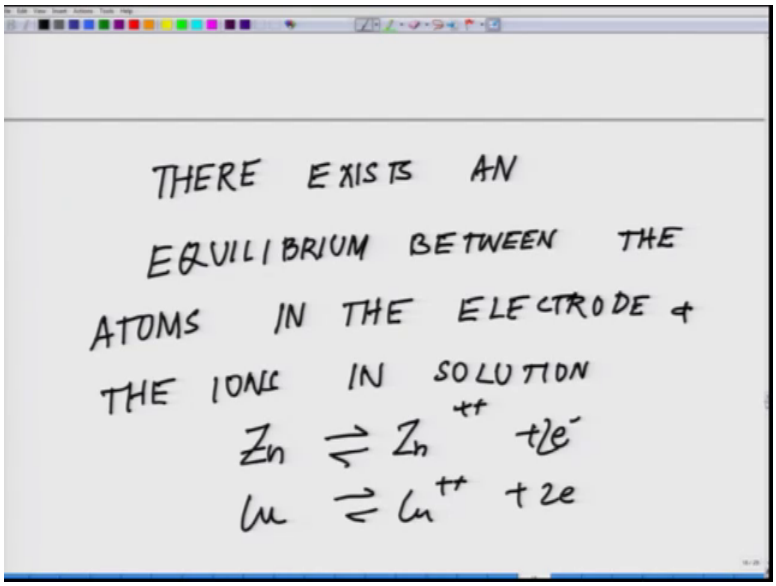
(Refer Slide Time: 18:54)



In this cell if we talk about in this cell both electrodes zinc and copper are surrounded by their own solutions. So, for example, copper is surrounded by Cu SO 4. So, this is solid and this is in that liquid copper sulphate.

Similarly, zinc which is the solid whereas, zinc sulfate is the liquid by their own ionic solution, they are existent equilibria between the atoms in the electrode and the ions in the solution. Now, this part is extremely important to understand.

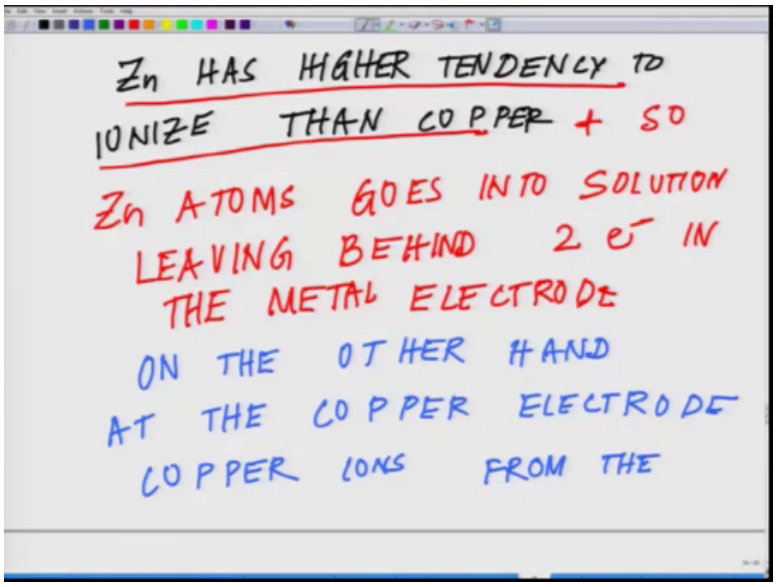
(Refer Slide Time: 19:34)



So, please be very careful and this is one fundamental concept there exists and equilibrium between the atoms in the electrode which is the solid part and the ions in solution.

So, here is zinc and Zn plus plus plus 2 electro electrons which it gives out where is copper sitting here Cu plus plus plus 2 electrons. But here you have to realize that zinc has greater tendency to ionize than copper.

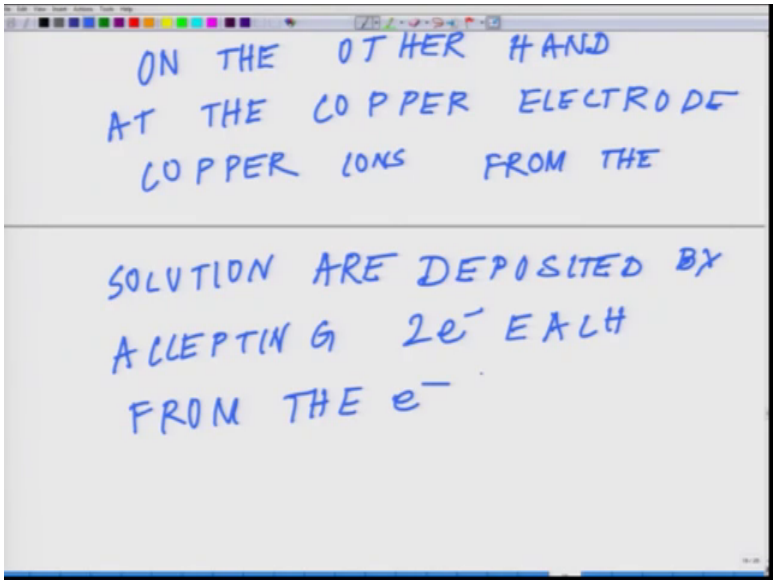
(Refer Slide Time: 20:51)



In other word zinc has higher tendency to ionize than copper. I am highlighting this part because this is the key to understand this and so zinc atoms now see the reactions at the top, zinc atom goes into solution leaving behind 2, leaving behind 2 electrons in the metal electrode.

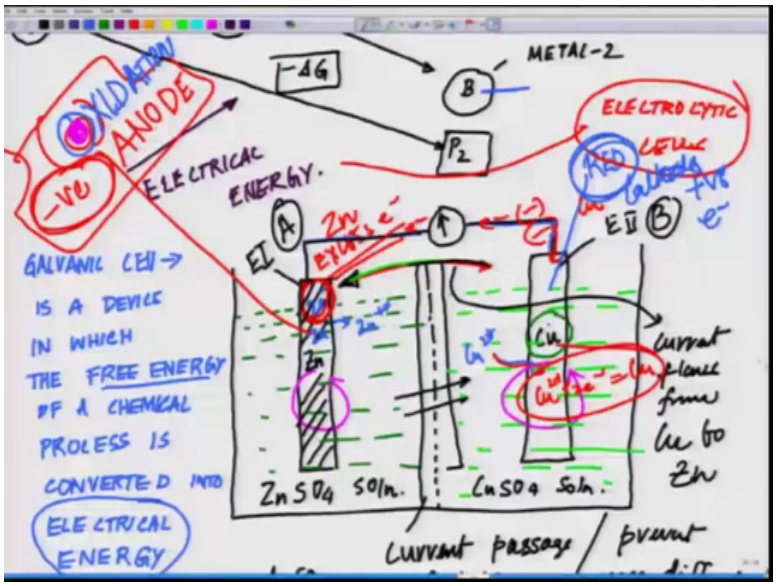
On the other hand if you look at it now let us talk about a copper electrode, on the other hand at the copper electrode copper ions from the solution are deposited by accepting 2 electrons each from the electrode. So, essentially if you look at it I try to understand what I just now mention.

(Refer Slide Time: 22:45)



So, zinc atom goes into solution. So, you have the zinc electrode. So, here is the cell.

(Refer Slide Time: 23:35)



So, here on the on the zinc electrode what is happening? So, zinc is getting ionized. So, Zn plus. So, here you are left with 2 electrons on the zinc this is what is happening and it will do it faster as compared to copper. Whereas, in the copper, so you have to Cu 2 plus. So, this has a tendency to accept electron very faster. So, in order to accept electron what it will do, it will try to move in out here and what essentially will happen is it will be needing an electron and from where it is going to get an electron and this part is very important.

Coming back, we talked about that the zinc has a greater tendency to ionize then copper and so the zinc atom goes into solution leaving behind two electrons in the metal electrode. So, the metal electrode is now having excess electrons. These are the two excess electrons which are there. On the other hand at the copper electrode the copper ion from the solution are deposited by accepting 2 electrons from the electrode. So, there is an excess of electrons at the zinc electrode said, here you have an excess electron add zinc and there is a deficiency of electrons at copper.

So, there is an excess electron as a zinc electrode and a dearth of the same at the copper electrode when the circuit is complete now you are completing the circuit. Now, once you complete the circuit the electron flows from the zinc to copper. So, the electrons from here are now traveling here and they come here and those copper ions which are deposited here becomes Cu 2 plus plus 2 electrons become copper. So, there is a copper

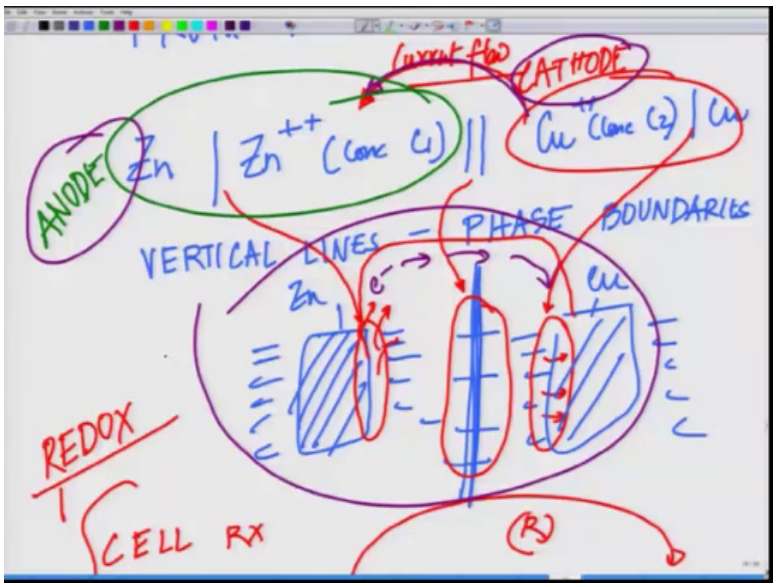
deposition which happen. So, this is how the electrical energy or current is produced which may be used for the purpose of external work. So, this is what the fundamentally what is happening.

It is obvious that the zinc electrode where zinc gives up electron. So, here you are having the oxidation is happening occurs and is the anode or negative electrode. So, this is considered as negative electrode because it is having excess of electrons out there and this is termed as anode.

So, there is an oxidation happening to remember, here it is there is an oxidation, oxidation. Similarly the copper electrode where copper ion takes up electrons copper ions copper ions are coming here and coppers ions are taking up electrons there is a reduction process happening, there is a reduction process which is happening and this is called a cathode or a positive electrode.

So, these are some of the basic fundamental one has to understand and a galvanic cell could be represented. So, there is a way to represent it by simple representation.

(Refer Slide Time: 26:52)

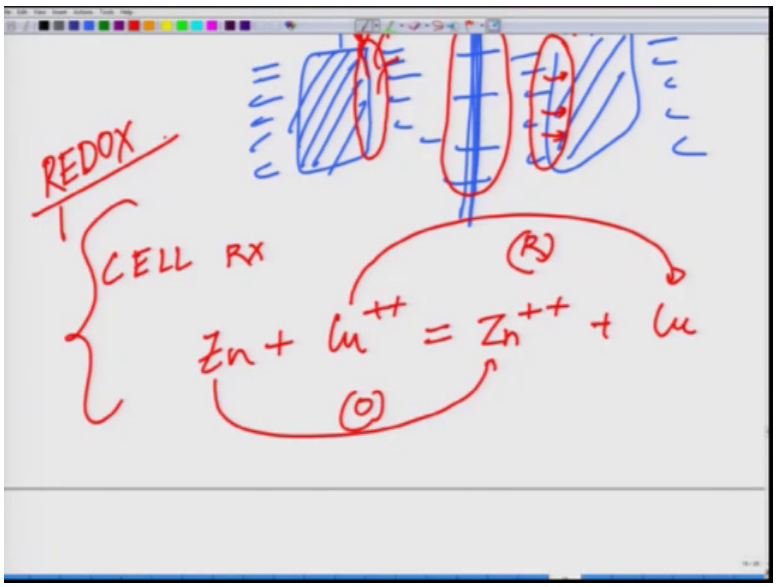


So, here you have the zinc zinc plus plus this is what is happening, this is concentration C 1 the double line. So, you have copper plus plus from concentration C 2. So, this is from the solution coming to copper.

So, where the vertical lines, these vertical lines indicate the phase boundaries the different phase boundary. So, you are seeing there are two phases one phase one phase is. So, if you look at the electrode. So, here is one electrode say this is the zinc electrode and this is the zinc solution and here you have the membrane in between semi permeable membrane and you have the copper electrode and this is the copper sulfate solution.

So, the first phase boundary is here and the second phase boundary is here. So, that is why there are different phase boundaries and these vertical lines are indicating. So, this is that phase boundary which is shown by double lines and this is another phase boundary and this is the third phase boundary. So, there are 3 different phase boundaries. This is where chemical reactions are happening when we are connecting this. So, realize, this is the way you are indicating the reaction and the real reaction is something like this the cell reaction or electrochemical cell reaction is like this.

(Refer Slide Time: 28:41)



So, you have zinc plus copper plus plus and is equal to zinc getting oxidized plus copper. So, zinc here went through an oxidation copper, went through a reduction and this is what the whole redox chemistry is all about.

It is usual custom to write the anode of the cell at the left. So, here we are writing the anode if you look at it. So, here you are having the anode written on your left whereas, the cathode on simulate is written on the right.

So, this is a customary thing representing a cell it is also our common convention that the current is the external circuit is considered to flow from cathode to anode. So, the current that is why the arrow is like this from cathode to anode, so this is a convention. So, current flow is opposite. When we talk about the current flow we talked about the flow of electrons. So, it should be in the direction of electron right, but the convention is just the reverse. So, please do remember though we know that on the zing the electrons from here are moving like this, but it is funny when these conventions were made they considered 8 in a reverse way.

So, if you look at it, it is the usual custom to write the anode of the cell on the left and cathode to the right representing yourself this is what we talked about cathode and anode and the left and the right respectively. And it is also our common convention that the current is the external circuit is considered to flow from cathode to anode as the direction shows opposite direction to the flow of although the electrons are flowing through the where in the opposite direction from zinc to copper though electron flow is in this direction.

So, please remember this fundamental the flow of current and the chemical changes are the electrode continued as long as the circuit is closed the chemical action ceases when that circuit is left open and there would be no flow of current. Obviously, if you disconnect the circuit there will not be any flow of it.

And I will close in here and the next class we will talk about what are reversible and irreversible cell and how we measure this whole thing. So, I will close in here and please go through it carefully because I try to be as simple as possible, but then too if you have a confusion then on the forum you can send questions plus please understand this because if you understand this basic once and for all trust me you can do wonders and you will do.

Thank you.