Non-Ferrous Extractive Metallurgy

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Concluding part of Module – 4 (Contd.)

Friends, we discussed in the last lecture, some aspects of electrolysis, and I emphasize the importance of limiting current density. And it arises as I mentioned very often out of a diffusion controlled process, where the diffusion of cations towards the cathode is slow compare to the discharge reactions at the surface. And when that happens, we have to concept of a limiting current, which means for a given area of the electrode, there is only this much of current we can pass. Not only limiting current, we divide that by the area of the electrode we have limiting current density. So the electrode has a maximum metal deposition rate.

This brings us the question, brings us to the question as to what we do then to increase the productivity of electrolytic cell. One obvious answer was to increase the area by increasing the width not the depth of the electrode, and then beyond that have multiple cells. So, because in one given cell with a given electrode area, you cannot produce more than certain amount, you can always do that if you have many more cells. So, most electrolytic plants will have many, many cells; if not like a pyrometallurgy, you have one reactor which produces a lot of metals.

Here, we will have many, many cells often called pots which are actually electrolytic reactors. So, the reaction taking place there, so we will have many of them. Question is, how do you arrange them? Now, we have seen two basic things that if you put all the electrolytic pots in a series, so the same current flows through and the current level is low. So the i square r loss in the electronics electrical circuit will be low, but the voltages get added; so on the whole you are operating the higher voltage from one end to the other end.

But there the disadvantage is if one pot is in trouble, then the entire line is in trouble, you cannot repair one particular pot. You can eliminate this problem by putting all the pots in parallel, and then the current which comes get split into the pots in parallel, and they merges again and goes out. So the current increases, but the voltage is low, because they are operating all the pots are operating under the same voltage which can be given from two bus bars. So, these are the two extremes.

There the advantage is that your voltage requirement is low; you can take out any pot at a time if you need repair of whatever, but your current requirement is i; i square r loss will be high. For that, you have to provide for adequately thick electronic circuit so that the electronic resistance is cut down and you do not waste energy in heat losses in the electronic circuit. Now there are other ways you can think of doing things in practice.

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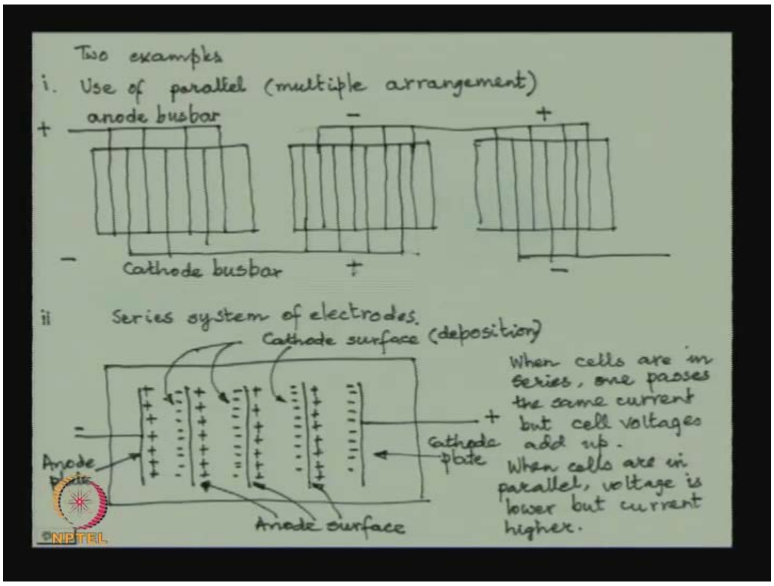

Two examples

i. Use of parallel (multiple arrangement)

ii Series system of electrodes.

When cells are in series, one passes the same current but cell voltages add up.

When cells are in parallel, voltage is lower but current higher.

Look at the slide for example; here, we show what we call a series parallel arrangement. Now what is it that it means; now this is a collection of electrolytic cells in this there are number of cells you have anode, cathode, anode, cathode, anode, cathode, anode, cathode, they are all in series. Here are also several cells in series; these are also several cells in series. The sorry this this this are in series, but look at the cells here they are arranged in parallel why because you have an anode busbar and the cathode busbar. From the same cathode and anode, you are supplying this current to this cell this cell this cell this cell; the same current is split into four and they again go they split into four and they again split into four.

So, these are parallel arrangements parallel arrangements parallel arrangements put in series. Now here, what is happening you have a cathode and anode which constitute a cell then also, we have a anode and cathode constitute a cell anode and cathode constitute cell it goes like that. So, you have a series parallel arrangement which has its own advantage; it is a compromise between parallel and series arrangement. This another very interesting way sometimes the electrolysis can be carried out. It is that, there is a whole lot of electrodes put in like this; one side is anode area; this is cathode area.

This is anode, cathode, anode, cathode, anode, cathode, anode; so if we suspend in the electrolytic pot, a number of electrodes like this then, metal will be deposited in this surfaces only; these are cathodic surfaces and the anodic reactions will takes place here. Such cells are known as bipolar electrode cells means, an electrode is bipolar. On one side it is plus the on the other side it is minus. I will show you an application of this in a process that almost became successful for aluminum electrolysis. So to summarize when cells are in series one passes the same current, but cell voltage adds up. When cells are in parallel voltage is better, but current can be high; we can have what we have here parallel series connection.

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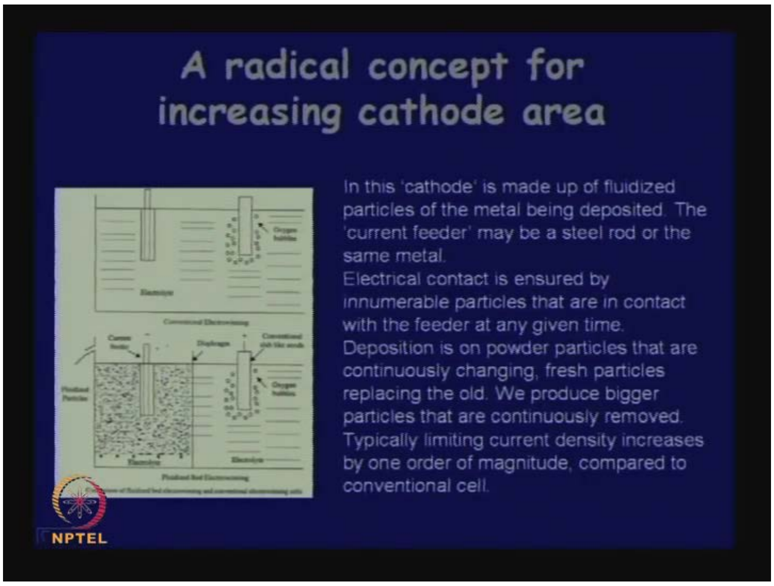

A radical concept for increasing cathode area

In this 'cathode' is made up of fluidized particles of the metal being deposited. The 'current feeder' may be a steel rod or the same metal.
Electrical contact is ensured by innumerable particles that are in contact with the feeder at any given time.
Deposition is on powder particles that are continuously changing, fresh particles replacing the old. We produce bigger particles that are continuously removed.
Typically limiting current density increases by one order of magnitude, compared to conventional cell.

We can have bipolar electrodes; these are various way of handling electrodes in a system. But now, let me come to a very interesting development which is the semi commercial state and it is a very radical way of thinking. Some researches argued that, our problem is that an electro surface is limited. So in a given volume, we have an electrode current is limited. They said why cannot you think of a different kind of electrode which is not a plane planar solid electrode, and they came up with the idea of a fluidized bed electrode.

Now, what is a fluidized bed electrode? For that look at the slide, in a normal set up what we have is an electrolyte and here is a cathode and here is an anode and suppose, it is an aqueous electrolysis where oxygen bubbles are coming, and here metal is getting deposited. In a fluidized bed set up we separate the two chambers. The anode remains as it is because it is a permeable diaphragm, a kind of membrane the electrolyte permits. But, in this chamber we have a current feeder then, there is a diaphragm here through which electrolyte is pumped, and the whole lot of particles are fluidize; these are particles of the metal that are supposed to be deposited here.

The suppose a metal m in this solution is to be deposited. We take powder of metal m have them dispersed in a fix suspension, and that is fluidized means, if you leave the powders as it is perhaps, they will all come here and make a bed, but then this electrolyte has to be pumped through the bottom with a certain speed so that they are thrown up and they are fluidized; they cover the entire area

Now you might say, what is happening to the electrolyte you are concentrate flowing up? It will come out this way; how I will tell you. Now, what happens when you have a fluidized bed electrolyte; you have a current feeder stuck into an electrolyte where there an infinite number of metal particles floating around now. At any instant, there will be innumerable number of particles in contact with the electrode surface; in contact with each other and this chain now functions at the cathode surface. So the cathode is no longer a planar surface, it is the surface of infinite number of fluid fluidized particles of that metal which are in motion, but at any instant many of them make a change, many of them are in contact with the feeder, and the surfaces of all this particles provide a surface for electro deposition.

Now, look at this beautiful concept. You no longer have a plane surface on which metal is deposited. The metal now can deposit on a much larger surface; the surface area provide by the surfaces of this fine particles. Now, it has been found by actual practice that if it is done properly, you can increase the limiting current by an order of magnitude instant times which means, compare to a plane electrode. When you have this fluidized bed particles providing the surface for electro deposition, the available surface area is more than ten times. What does it mean? It means, if the same cell, same size almost the same arrangement accepting that instead of having a flat electro surface if you provided a mass of particles in fluidized bed, we can now bring in ten times more current to the cathode surface and therefore, productive can be ten times more.

Now, where is this metal going to be deposited? It is not on that surface. The surface is not there; there is no planar surface for deposition what we had initially an electro surface. Here, it is only a current feeder may be a sheet of the metal; may be a rod of the metal. The metal is primarily being deposited on the particles that are in the fluidize state which means, if you provide a seed; a seed means certain number of particles. They begin to grow because on them metal is being deposited and they are not static means, the particle which are in contact to the feeder or in contact with each other are changing constantly.

So means, a certain n number of particles were in contact with the feeder and contact with each other metal deposits on them and then they run away fresh particles come. So the overall effect of this is the particles continue to grow. So you bring in the seeds; seeds continue to grow and because there is a continuous flow of electrolyte from the bottom for fluidization, this particles and if and if and the electrolyte will flow out of here, and you must have a screen to take out certain fraction of particles. So you bring in more and more seeds, so by adding certain amount of smaller size particles, you get larger size particles; you can do something more also. In this, you can take a different kind of metal particles, fluidize them and have them coated with the metal that is being deposited you can do that also. Normally, you would need that; you are interested in producing a certain metal from the electrolyte

So you take the same metal particles, fine particles have them fluidized and on those particles fresh deposition takes place; so each particles increase a bit in diameter and since, there is a continuous flow, they are discharged with electrolyte; so it is a continuous process. You go on feeding final electrode metal particles they become slightly closer you take them out. Product now is not a is not a layer on a planar surface no; the product is a powder a fine powder which is coercive that the powder used in the fluidized bed. Now sometimes, it can be an advantage; you might like to have the metal in a particular form in powders. It will go directly for powder metallurgy. It can have other application.

So, this is the principle of fluidized bed electrolysis. So I will I will repeat this. In this, the cathode is made up of fluidized particles of the metal being deposited. The current feeder may be a steel rod or the same metal; it can be sheet also. Electrical contact is ensured by enumerable particles that are in contact with the feeder at any given time and with each other. Deposition is on powder particles that are continuously changing fresh particles replacing the old. We produce bigger particles that are continuously removed. Typically, limiting current density increase increases by one order magnitude compared to the conventional cell. Now in principle this is very good; what are the disadvantages? There would be disadvantage. Firstly, that you are not getting a consolidated metal layer on a plane surface. Secondly, you end up with powders which you may or may not wanted if you if you want it fine. Secondly, you are now do not have a static system, you are continuously pumping something, you are fluidizing.

So that brings in more plumbing, that brings in requirements of handling the discharge, separating the coarser particles, constantly brining the fresh finer particles, etcetera. Although, this has been proved to be very effective not many industries actually operate on this principle because we will find again and again that when you R and D, it come up with exciting findings exciting findings, but the problem comes. Technologically we are not very easy to adopt. That is where we should know the differences at step. You know what is research? Research is there is a phenomenon we want to study. When you do R and D development that research has a goal; you are doing it for particular purpose.

Now here, fluidization would be a research topic; how it is fluidize; what should be particle size etcetera. If we want to make a fluidized bed set up to study this phenomenon whether it can be applied be in an electrolytic cell, it becomes R and D. But then, technology is not R and D. Technology asks two other questions; are they technologically feasible? Are there methods of fluidization? Is there a suitable feeder material? Will it apply on a large scale? These questions are questions of technology.

Suppose, technologies also satisfy to be a commercial process then, there are some additional requirements, and there will be are they there economic advantageous. So from research to R and D to technology then a commercial process cannot be there unless there are questions of profit answer properly.

Will it compete with another called standard process and be more profitable. It is giving you ten percent more productivity in one cell at what cost. The industry may say why bother about it, I would rather have different cells and get the same result without changing anything that I have. So the question of economic profitability comes in. That is why after R and D, we do what we call techno economic analysis t e f r; techno technical feasibilities and economic criteria. Now, even if you have satisfied all the criteria of technology and commercial process, it may not be an actual process in operation because then, there are other questions. You have answer the questions of technical, scientific feasibility, technical feasibility and economic feasibility. Then there are other questions; questions like do they confirm with environmental regulations? Will they satisfy socio economic conditions, labour requirements, many government laws, regulations? So there are many, many things.

So we may develop something in a laboratory, but very often it goes up to a technology then stops or it can go to a commercial step, but it may not be a an industry. Anyway, I am I am digressing; what I am saying is an exciting idea. There are many many such exciting ideas in non ferrous metallurgy. Some have gone all the way to become a viable commercial process, but many have not gone their full distance and you should always know why they have gone the full distance. That is the reason why this aluminum electrolytic cell that we discuss which is about hundred years old. Still basically remaining principle what it was 100 years ago. Blast furnace process for example, is 400 years old; still operates the weight operator 400 days. There be many refineries, but they does not mean we give up because when you come to the modern develop developments when you talk about nuclear metallurgy, nuclear metals all these have come because we understood the theory and there are lot of R and D.

Now, coming back to this question of fluidized bed electrolysis; in theory it can produce ten times as much as in the sensor, but there are technological problem. The problem handling large volumes, you need pumps which will continuously pump things, the pumps may fail, you need more plumbing, you need if you have seen fluidized bed set up, there are some very interesting requirements of fluidization they have to satisfy.

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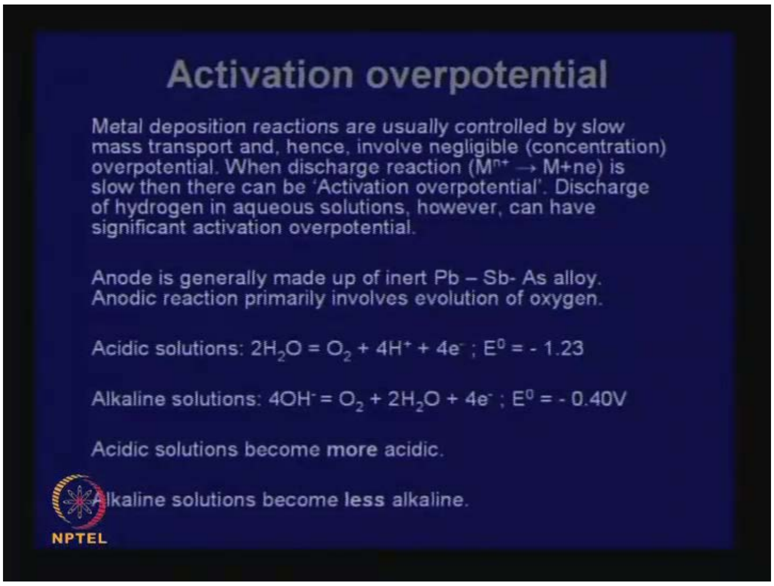

Activation overpotential

Metal deposition reactions are usually controlled by slow mass transport and, hence, involve negligible (concentration) overpotential. When discharge reaction ($M^{n+} \rightarrow M+ne$) is slow then there can be 'Activation overpotential'. Discharge of hydrogen in aqueous solutions, however, can have significant activation overpotential.

Anode is generally made up of inert Pb – Sb- As alloy. Anodic reaction primarily involves evolution of oxygen.

Acidic solutions: $2H_2O = O_2 + 4H^+ + 4e^-$; $E^0 = -1.23$

Alkaline solutions: $4OH^- = O_2 + 2H_2O + 4e^-$; $E^0 = -0.40V$

Acidic solutions become more acidic.

Alkaline solutions become less alkaline.

Anyway let us move ahead. Now, so far we have been discussing electrolytic reaction where it is diffusion that controls the whole thing because the diffusion is slow the side reaction with the surface is fast, and that is what I have said here that metal deposition reactions are usually controlled by slow mass transport and hence, involve negligible concentration over potential when discharge reaction that is M n plus to M plus n e is low then, there can be activation over potential. Now there are situations where the process is not diffusion controlled means, the it is not because of a gradient that the metal ions are coming to the surface, and that is defining the steps. Actually, this step is very fast that metal ions going to the surface is not a problem. It is at the surface the discharge is slow. There are not many examples of this, but there are some and this is what gives rise to activation over potential.

This happens in the case of discharge of hydrogen in aqueous solutions, because this can have significant activation over potential. Now here, let me stop for a moment and tell you that, this is a very interesting exception which is a very happy exception. There are many such happy exceptions in the world. One I suddenly thought of is the example of ice. You know ice floats on water; if you have not thought about it think about it. This is an exceptional thing that nature has done, because most solids when they melt they occupy more volume because after all why does a solid melt.

Now, one simple theory to explain the phenomenon of melting is that you have a crystal lattice. Now in the lattice you bring in some empty spaces like holes so that the volume increases and the lattice is no longer rigid. So it is becomes fluid; it becomes a liquid. So in most cases, the liquid occupies more volume than the than ice which means, more volume than a solid which means, solid always has more density than the liquid, and if you melt many metals, you will find the metal melts and the liquid is on top metal; solid is at the bottom because heavier.

In the case of ice because of a strange phenomenon ice becomes lighter. It is a very rare exception; there are one or two metals with that happens. Again let me repeat most solids are denser than liquids. Ice is an exception; it is lighter. So what happens when ice melts it floats. Of course, it floats also so that only a fraction is above liquid 9 times is below liquid, but this is vital. In the arctic areas in winter when everything is covered by ice, there is water below the ice because ice is floating and because there is that water, the arctic life exists. Fishes do not die; had ice been heavier than water, ice will form go on sinking water will be on top; it will go on freezing; everything all animal life will die. So the God has created that exception that ice will float with most of it below the surface, but below that water will remain and ice is an excellent insulator. So once it floats the top, it will not allow the heat go it in; the fishes can survive at the bottom. It is a very happy exception.

In metallurgy, you have a very happy exception and this exception happens in the case of hydrogen evolution. Now, when we have an aqueous solution electrolysis, and we are and we are evolving hydrogen then, a very interesting phenomenon take place because the hydrogen atom is very small. It diffuses very fast through the aqueous electrolytic media. Iron will diffuses very fast; it go to the cathode. It is the discharge of that hydrogen ions on the hydrogen electrode that is low.

So there will be an accumulation of hydrogen ions because it is coming very fast; it is accumulating so that hydrogen gas, hydrogen potential is going to change; is going to increase. See the implications of that, but before that let me read the slide. When discharge reaction metal metal plus ne is slow, there can be an activation over potential discharge of hydrogen in aqueous solutions. Here, put hydrogen in place of M; there can be activation over potential which means, discharge of hydrogen in aqueous solutions changes the hydrogen potential. Now let let let me stop for a moment.

In aqueous electrolysis, anode is generally made up of inert lead antimony arsenic alloy. Anodic reaction primarily involves evolution of oxygen. In acidic solution what happens, water is being dissociated to produce oxygen and hydrogen ions. In alkaline solutions, you are producing alkali disassociates gives oxygen, water and acidic solution therefore, become more acidic and alkaline solutions become less alkaline. So in acid leaching process that is an advantage. Acid leaching processes followed by electrolysis. Let in theory consumes no acid because you have consumed acid produced a an electrolyte; it generate acid it goes back. Now, suppose you have a solution of zinc salts in an aqueous solutions; you are trying to electrolyze a zinc.

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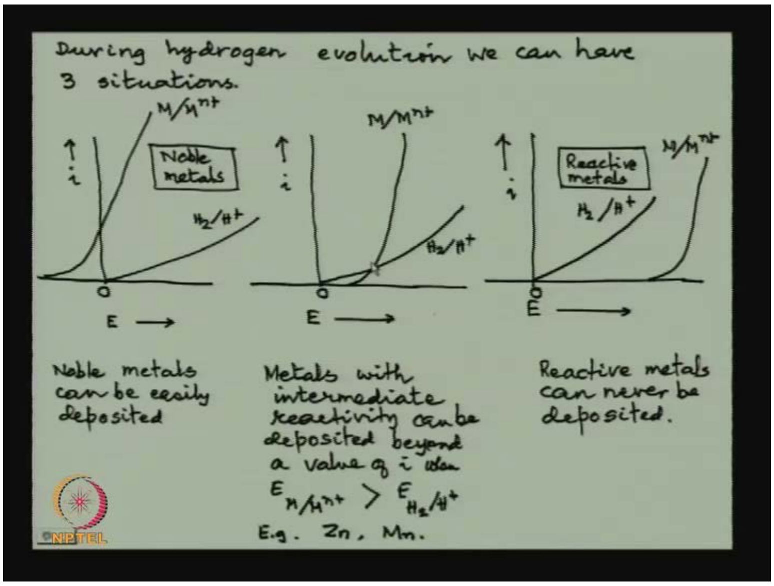

During hydrogen evolution we can have 3 situations.

Noble metals can be easily deposited

Metals with intermediate reactivity can be deposited beyond a value of i when $E_{M/M^{n+}} > E_{H_2/H^+}$

E.g. Zn, Mn.

Reactive metals can never be deposited.

Now go back to the electro e m f series electro motive force series. Remember, electro motive force series is where we showed, which metals are active, which metals are not active and I will show you the series once again; I have with here. Electromotive force series; now here, right in the very beginning if you can look at what we have it here remember, in the very beginning of the of my course, I had said that all metals can be arrange in terms of reactivity, and one common way would be in terms of electrode potential in aqueous solutions. In an electrode potential series, we had some very highly reactive metals like cesium, lithium, potassium, calcium, sodium, magnesium, titanium, aluminum, etcetera where there was no question of getting them from electrolyte from electrolyte aqueous solution because they are so reactive; the moment they are produce they react with water and displace hydrogen because hydrogen comes below them.

Now, on the other hand below hydrogen below hydrogen, we have noble metals copper, silver, platinum, gold etcetera always you can electrolyze in aqueous solutions and they will come out because they do not react with hydrogen. Problem is in places which are close to hydrogen. We this series has been drawn with hydrogen potential as 0; H 2 H 2 H 1 potential as 0 and slightly above them is zinc, chromium, manganese up to manganese. Now normally, you should say that you can never produce these metals by electrolysis of aqueous solution because they should react with acid and produce hydrogen, and this should happen, if you have mild acid solution, if you put zinc in that zinc will dissolve hydrogen will come out. It will put manganese or chromium same thing should happen because they are more electro positive than hydrogen, but the situation changes during electrolysis and it can change only up to manganese. Metals up to manganese can be produced by electrolysis of aqueous solution because of this exception that hydrogen gives rise to activation over potential.

If we plot the situation schematically, we have three situation; I am plotting here the change in electrode potential with respect to current or current density whatever. Now the more current you pass, the more there is a change in the electrode potential; why? Because, when you are passing current more and more hydrogen is coming and hydrogen gas and hydrogen ion potential will increase. Me t metal metal ion potential if you compare will also increase, but in the case of noble metals, this is always higher than this. So noble metals can always will be deposited no matter what is the current we are passing.

On the other hand, if you go to the other extreme very reactive metals like as I said cesium, sodium, potassium etcetera, there also with increasing current density electrode potential can change for both this hydrogen hydrogen ion and metal metal ion, but there is no chance that you can go to high enough high to make metal metal ion potential higher than hydrogen hydrogen ion potential. However, in the case of this intermediate metals as I said going up to manganese and zinc and manganese, there is a cross over means, if you increase i hydrogen hydrogen ion potential can change like this; metal

metal ion potential can change like this, but beyond a certain value of i hydrogen hydrogen ion potential is more.

So, metal can be deposited at the cost of hydrogen means normally, if you are putting zinc in an acid solution hydrogen will evolve, but when current is passing because of this phenomenon hydrogen will not evolve and metal will deposit. This is the basis of zinc metallurgy that we will see that zinc can be produced from aqueous solutions even though in electromotive force series, it is more electro positive than hydrogen.

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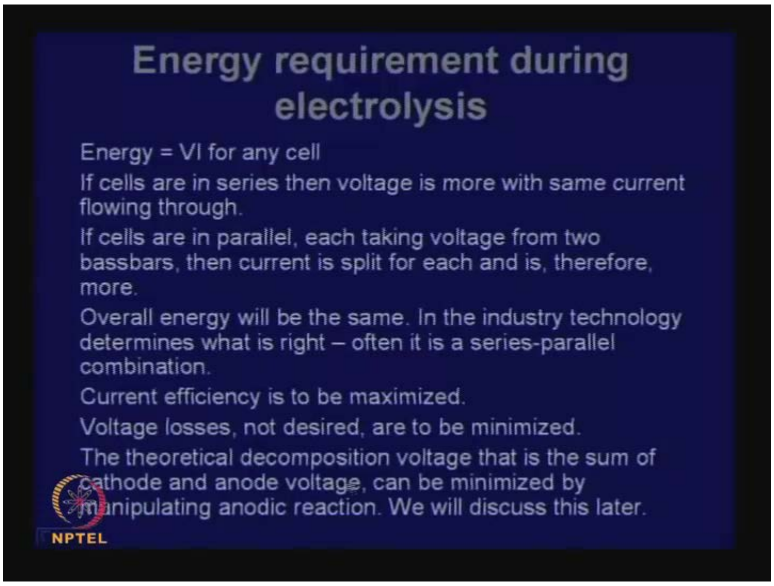

Energy requirement during electrolysis

Energy = VI for any cell

If cells are in series then voltage is more with same current flowing through.

If cells are in parallel, each taking voltage from two bassbars, then current is split for each and is, therefore, more.

Overall energy will be the same. In the industry technology determines what is right – often it is a series-parallel combination.

Current efficiency is to be maximized.

Voltage losses, not desired, are to be minimized.

The theoretical decomposition voltage that is the sum of cathode and anode voltage, can be minimized by manipulating anodic reaction. We will discuss this later.

Now, let me summarize what I have said this for before I proceed. In an any electrolytic cell, the energy required would be voltage into current if cells are in series voltage is more; same current is flowing through current is less. If they are in parallel, current has to be split up; current is more. Voltage comes from the same busbars so voltage is low. Overall energy will be the same. In industry technology will determine and it will be summary in between you can have series parallel, but emphasis would be in parallel so that you can remove any spot at any time you like. No matter what you do, our aim will be to maximize current efficiency because you do not want the current to go for anything other than metal deposition except in the case of high temperature electrolysis.

There the current also has to provide heat which after all you will not heat and apart from outside, the current itself will generate heat. So that will come from the resistance of the electrolyte; so that voltage drop, we have to account for; that is advantageously used, but we would not like energy loses in electronic circuit or in the in the electrodes or at their joints etcetera those are wastage. We not only want current efficiency to be maximize, we also want voltage losses not desire to be minimized, and we want energy efficiency also maximized. I will come to this energy efficiency in theoretically.

The theoretical decomposition that is the sum of cathode and anode voltage can be minimized by manipulating anodic reaction. Now, let me explain this. Essentially, the voltage requirement for any electrolytic cell as I have discussed earlier has many components. First is, you need a voltage to decompose the solute then, you have voltage to overcome over potentials. They need a voltage to overcome the resistance of the electrolyte then, you need voltage to overcome the resistance in the electronic circuit then, you need some voltage to overcome the resistance in electrodes of which the resistance of the electrodes resistance in the electronic circuit, they must be minimize because they only heat up the joints, electrodes or the or the circuit

For aqueous solution yes, you can minimize the resistance of the electrolyte. For that, we can bring in the electrodes very close together; over potential there is not much we can do. It can arise out of… It is a diffusion control process through concentration over potential or if in the case of hydrogen discharge, it can come from activation over potential. But now, examine the basic thing is you need a potential to break the solute. Now suppose, the solute is M x; m gives you the cation M; M plus it goes to the cathode; x gets an anion which gets discharge at the anode. We are really interested in metal deposition. This reaction can be a many kinds. We we can manipulate the anode reactions. Why should we manipulate? Because, the total voltage that we require for deposition or breakage up will be sum of this potential metal metal ion potential and the anodic potential. Now, the cathodic potential nothing you can do; metal ion to metal you have to deposit. But here, there can be different kinds of reactions and that can change the requirement of metal deposition from a solute.

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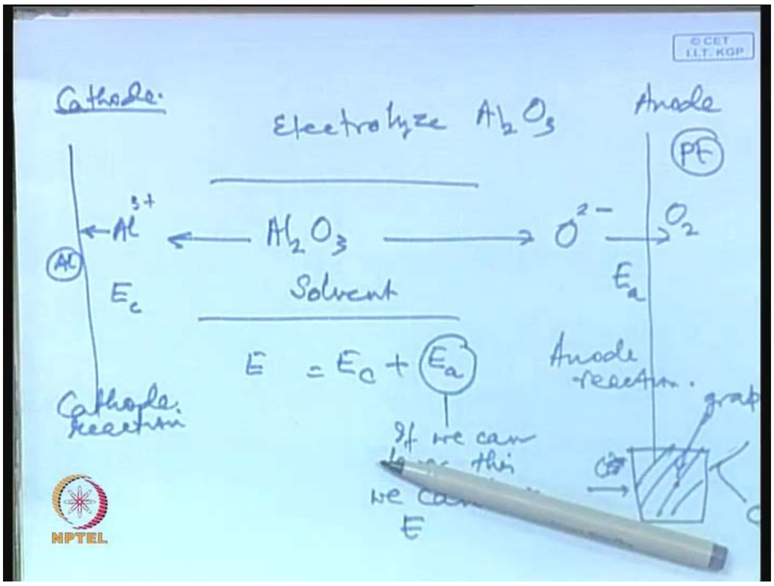

Consider an example; suppose, we find a solute in which we electrolyze, we will come to this in the next lectures Al 2 O 3; we have found a solvent. We will have to break it to bring aluminum and oxygen. We have to find here a cathode on which aluminum will get discharge produce aluminum. Here, we can think of an electrode anode. In theory in theory there can be a platinum where oxygen will evolve. So you are breaking aluminum into aluminum and oxygen. This is the cathode reaction; this is the anode reaction. There is a potential here required a potential here this and the total potential decomposition potential would be cathodic potential plus anodic potential. Can we lower this? If we can lower this, we can lower E and no harmed done. You are metal deposited you lower this. Can you do this? Actually, it happens in the case of aluminum electrolysis. What you do here? We do not have a platinum, we have a graphite electrode.

So, when oxygen comes here, it reacts to produce CO and CO 2; so the reaction is not oxygen ions giving you oxygen gas. It is oxygen ions coming reacting with carbon to produce C O C O C O 2 gases. So it is a totally different anode reaction and actually, it brings down the voltage requirement; why should we bring down? Because by this reaction, you are efficiently eliminating oxygen ions; you are consuming them means, you look at this way that, you have produce oxygen that oxygen is reacted with CaCo 2 to produce more stable compound. So you require in theory lesser amount of energy.

Now many, many attempts have been made to play around with anode reaction so that the total voltage requirement is low. Unfortunately, most these efforts have not been successful. When you come to discussing actual examples, we will see that. So now, I am coming with this to the conclusion of module 4. Now for now, I will lead you to module 5 from where we will start discussing extraction and refining of specific metals. Now, there is I can see a potential problem there because I will have to give you a lot of facts, and many of this facts have evolved out of centuries of practice. Like I have told you right in the beginning zinc, lead, copper they have been produced for hundreds if not thousands of years and many things have evolved.

I do not know, how they are evolved because without knowing the theory they come up with excellent findings and the still many people do not understand how they found out those things. But, many of the things that were done in the past still continuing because they are found to be theoretically sound today and it is like those ayurvedic medicines. So, many things have been found today that what is written in our ayurvedic text books 2000 years ago. Treatment of various diseases using various medicinal plants, they are actually valid and like the (( )) plants for example, its main ingredients is amla; it is been going on for many, many centuries.

But today, it is proven that amla is one of the richest source of vitamin C and it is very important vitamin C, and is one of the richest sources; how they found out? They found out basically by trial and error. Now so, when it comes to this medicinal things they say there is a difference between experimental research and experiential research that you do not do experiments to prove this or prove that you experience like yoga. In yoga penetrates are well established; you cannot prove that by experiments; you cannot say do 3 days, 3 hours and after one weak make measurements no, but experience over generous thing have shown certain things to be right; certain things to be wrong.

In the case of technological developments, there have been experiments and there have been are experiences based on which many things have been evolved. They have been proved to be very right. Now so, I will give you lot of facts that do this then, do this then do that and this I will give you many, many flow sheets. I do not expect you to remember this facts. I do not expect you to remember this flow sheets because they are in the literature. If you ever want to know what is done you can always go and refer to a book.

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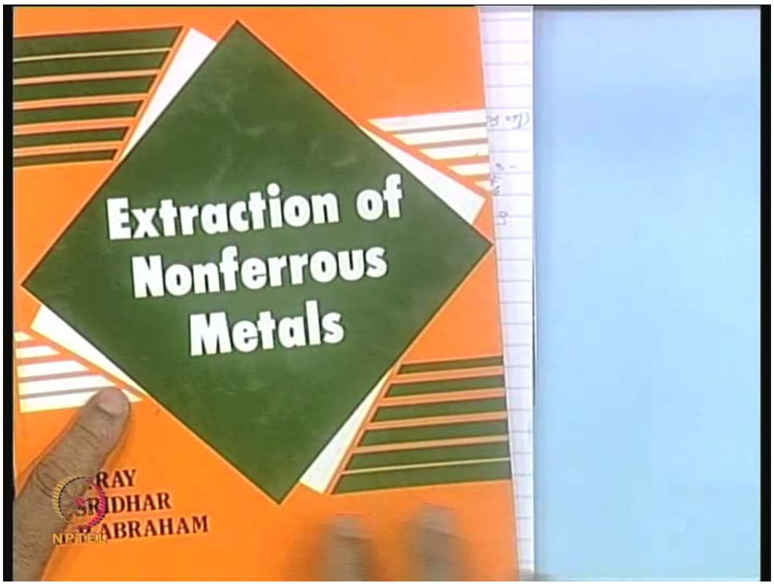

And I am again telling you the book now you will have to read is this book of mine called extraction of nonferrous metals by H S RAY, R SRIDHAR and K P ABRAHAM. It has been published by affiliated east and west press limited many years ago 84 first published. Its get repeated every year, but I am going to follow this book and also some material I am collecting from here and there. But, there are many things in this book I cannot discuss for example, there are flow sheets after flow sheets and data and facts and I have not go through all this; what will I do then? I will try to give you facts and discuss the why's of this facts. If this is done after this, why this is done? If something is not done, why it is not done? So, when I go for discussions of individual metals, please try to follow my discussion on why's and why not is. I need to give you some facts; I need to give you some flow sheets, some data because after all they have to go on the record.

And some do you might like to know, what is to be done there the thing should be available. Then, when you do that you will also know why you do that. But, again I am saying I do not expect you to know that remember the flow sheets; remember the facts. I would not emphasis the flow sheets, I will have to show them, but I will try to emphasis why something is done and some two similar things, why similar approach is not available. Now, I will start put a lot of emphasis on aluminum because after steel aluminum is going to be a backbone of our industry, and aluminum is very, very important as a metal, and discussions of aluminum; for that you will… I will again refer to two books.

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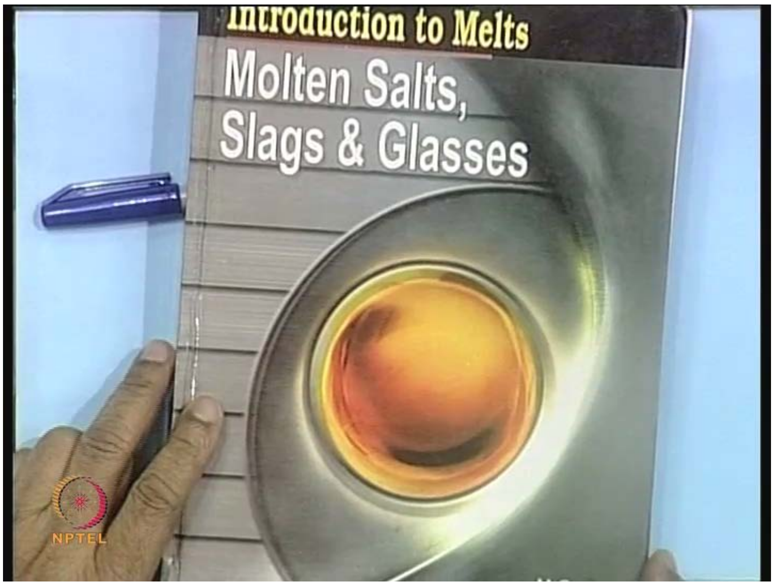

One book is on molten salts slags and glasses again authored by me. It has been published by allied publishers private limited, New Delhi a few years ago.

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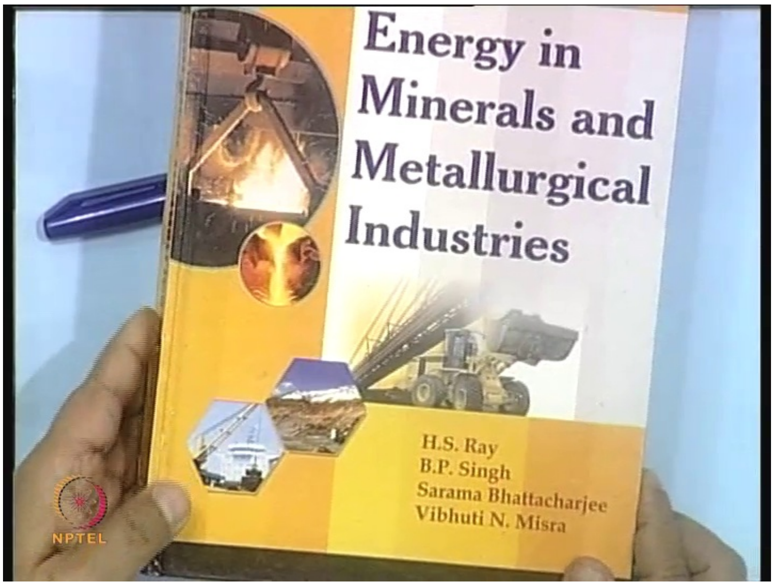

Another book to which I am going to refer, and from which I am going to take a lot of materials will be on this book, energy in minerals and metallurgical industries by H S RAY and others. It is also published by allied publishers limited, New Delhi. I will suggest that you should buy this book because if you want to be a metallurgist, this book will be very useful to you. I would also suggest that, if you have interest in nonferrous metallurgy, you can certainly buy the book on nonferrous metals. The book on few slats slags and glasses is slightly at an advanced level; this reference book, but you should try to refer it to this book specially, when I start discussing aluminum.

Now, let me introduce you to what I am going to do in the next module 5 because have to relate whatever I have done so far to that part. In the module 5 will be about production of metals from oxides. Now again, let me take you back to the lectures I deliver some time ago. I had said we are going to approach production of metals in this course not alphabetically, not starting with aluminum and ending with zinc no. Will proceed according to the sources from which they are coming and it so happens, some metals comes from oxide sources. Some we get from sulphuric sources sulphides. Some are produced from halides; they may be natural halides or there may be halide intermediates that have come from oxides or sulphides.

But basically, we start with the halides. Lastly, we will discuss metals which are noble metals which can which are in nature not has come from by the free state, and lastly we will discuss production of secondary metals; metals from secondary resources means wastes, these are the five categories. Now, we will start the next module with metals from oxides. It does not mean that they would all follow the same flow sheet and same metal no, you can have a metal a as an oxide, and metal b as an oxide is quite possible they will not be produce by the same metal, but you should know why they are not produced by the same metal. It is also possible that many of them would be amenable to the same method. So, you try to understand the logic of the similarities, and differences. Thank you and then, I will I will start the next lecture starting with metals from oxides, thanks.