Non-Ferrous Extractive Metallurgy
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Module No. # 01
Lecture No. # 01
Brief History of Non-Ferrous Metal

My young friends; I find myself, in a very unusual situation, where the students can see me, but I cannot see the students. I also do not know that what time of the day it is, when you are watching this video. I do not know whether to say good morning or good afternoon, or good evening. But one thing I know, for sure, I know what kind of people you are. Presently, I am a retired scientist. I retired 9 years ago, but I have been a teacher for many years at IIT-Kanpur and IIT- Kharagpur. I have taught hundreds of students in those institutions and elsewhere.

I have, specially, always vibes very well with the undergraduate students and I have found that, basically, every class was so very similar. There are always some students, who are very sincere; they take down notes. Copious notes. If I utter one sentence, they write down three sentences. There are some students, who are never looking at me. They are looking at the walls or through the windows, but somehow, I can sense that they were listening. When I asked them some questions later they could respond very positively.

On the other hand, there have always been some students who would be looking at me but they would be blank faces. It means they may be hearing at the most, but they would not listen and, obviously, there would be some students who would rather be elsewhere.

Now, as a teacher, as most of others who have been teachers, I would like to connect with those few people who are listening, and through them connect with the class. So, I assume that there is somebody there, with whom I am making a connection, and who will enjoy or at least try to enjoy, whatever he is learning.

Right at the beginning, let me say one thing very clearly that, if you try to enjoy or try to learn, then you would like the course. If you like the course, you will try to learn. So, it is a process that goes on. If right from the beginning if you take an attitude you know that this is a course you would rather not be interested in, and then you would find that it is not a course that is interesting to you.

Now, I must admit that this course does not have a very good reputation in the sense that many think non-ferrous metallurgy, is a very boring subject. They are not very wrong because the way it was taught at one time, was very wrong. People would take one metal at a time; talk about ores and minerals; talk about methods of extraction, their uses, and then move on to another metal and this makes it very descriptive, and I do not think any student would be interested in this.

If it is information to be given, a student may very well say that when the information is in the book then why should he to come to the class. If necessary, he will pick up the book and read it. As a teacher, I would not like to give the information because it is in the book; somewhere, some place you can find it. I would rather try to give you the principles that govern the extraction process of non-ferrous metallurgy; some logic in the subject.

If you get the logic then the subject is fun. If you do not get the logic, then it will be a descriptive course. And remember that this course, in the undergraduate years, has to compete with some fantastic other courses where there is so much of quantification, beautiful concepts; that is mathematics in thermodynamics, in kinetics, in microstructures, crystallography, metal forming, the principles of dislocation; beautiful concepts and there are also wonderful laboratories, which substantiate with what you learn in the class. In order to compete with that, non-ferrous metallurgy has to come up with logic of its own.

I had to tell the students, why he should also take non-ferrous metallurgy seriously or try to do that. I do not know now how much I will succeed, but definitely, I will try to give you the logic of the processes, rather than the details of the processes. I will try to avoid the details.

I will have to give you some flow sheets and some chemical equations because these information's are necessary. They will be in the records but I would not expect you to remember them all. When you would need them, you can always find the term but understand why certain things, are done in a certain way, and not in another way.

Now, when I joined IIT Kanpur, which is way back in 1967, the first assignment, given to me, was teaching of non-ferrous extractive metallurgy to undergraduate students. I know they were very bright people and the thing was taught in the fourth year. Since, I did not know the subject, I asked to some of my colleagues that why they were not teaching it, because obviously they were more knowledgeable also and are more senior.

I understood later that nobody wanted to teach the course, because they all thought it was a very boring subject, they were not very many good books either. I went to the library and I saw some books; they read like encyclopedias. A famous book, which was followed at that time as a textbook, was by Bray.

That book started with aluminum, the logic was that Aluminum starts with A, and it ended with Zinc because it starts with Z. Had aluminum been called as aluminum, it would have gone to the end, and had zinc been called something with A, it would have been discussed first then. This, I thought was ridiculous, and I thought the book gave information, but it is not a boo, which can be used for teaching.

So, I started writing a book and finally, with two other colleagues of mine, I wrote this book. This book was published way back in 1984, titled as "Extraction of Non-Ferrous Metals", by H.S. Ray, R Sridhar and K.P Abraham. I would follow this book to a large extent. It was published by, affiliated East-West Press Private Limited. It has not been revised, in the last 25 years and it is going to the thirteenth print.

So, many of the data given are old, but the principles are not old. The principles remain the same, but I would certainly update, as I go on. As I said, we have tried to give logic for this course in this book and to that, I will come little later.

The logic is simply is this; I would try to put all this metals in some groups. There will be four or five groups. They will be discussed in terms of their occurrence in nature. Because if they occur in nature in one form, then the processes for their extraction, would be governed by one logic, than if, they were present in another form. This is the whole idea, but before I proceed,

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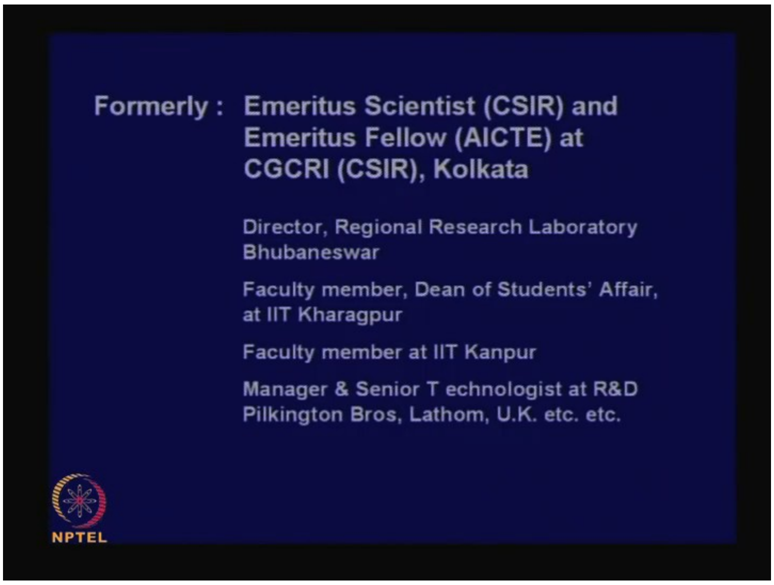

Just little bit about my introduction, where I was earlier, and everywhere I was very much concerned with non-ferrous metallurgy.

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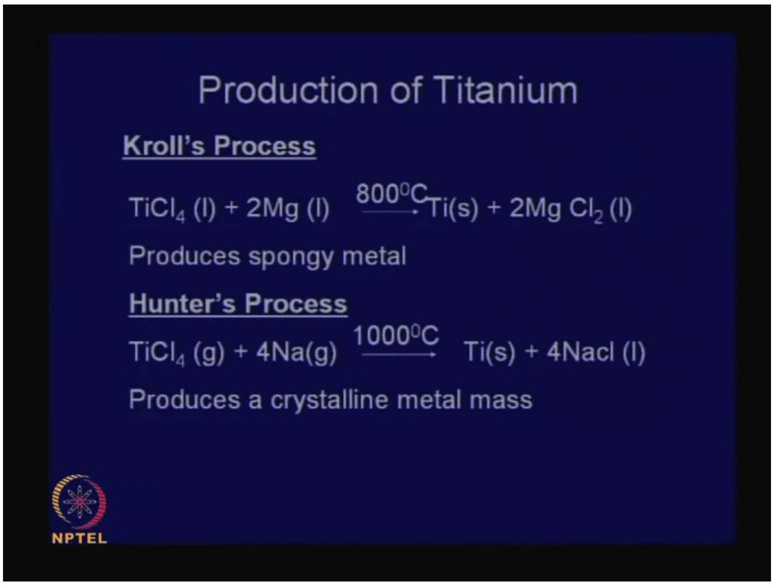

Now, let me discuss two equations. To tell you that when you write an equation in non-ferrous metallurgy, we are not doing what we do in chemistry. Had this been a course in chemistry, I would have said that titanium can be produced by reduction of titanium tetrachloride by magnesium or sodium. Period, and then I proceed to something else.

But, actually here, once I write these equations, I start thinking of something quite different from what a chemist will do. I would like to ask this question; why is it that in Kroll's process for magnesium reduction we get a product which is powdery and spongy; which is not a solid metal. Whereas, in the Hunter's process, we find that you get a crystalline product, which can be straight away rolled and made into a sheet. Why should this difference be there? There is a very interesting reason. I am not going to discuss everything now but I will hint at it.

Now, we look at the first reaction that is Kroll's process. It is what you call as a termolecular equation in a condensed phase. One molecular titanium chloride, finds two atoms of magnesium, and forms a titanium atom and magnesium chloride in bulk. There are atoms of titanium being produced one after another. There is no reason, why they should be consolidated, they remain separated and they produce a spongy mass.

Whereas in the Hunter's process, actually the way this reaction is written, is not the way the reaction takes place. Because, if you look at it, what the reaction says is, that you have a gas phase and if one molecule of titanium tetrachloride, which is moving around, finds four atoms of sodium at one place, then a reaction takes place.

What is the probability that four atoms of sodium, one molecule of titanium tetrachloride to come to one point? The probability, I think is not exciting! This reaction cannot take place like this, because a Penta molecular reaction, in a gas phase, is not what you expect to occur. Then what would be the other way of doing things.

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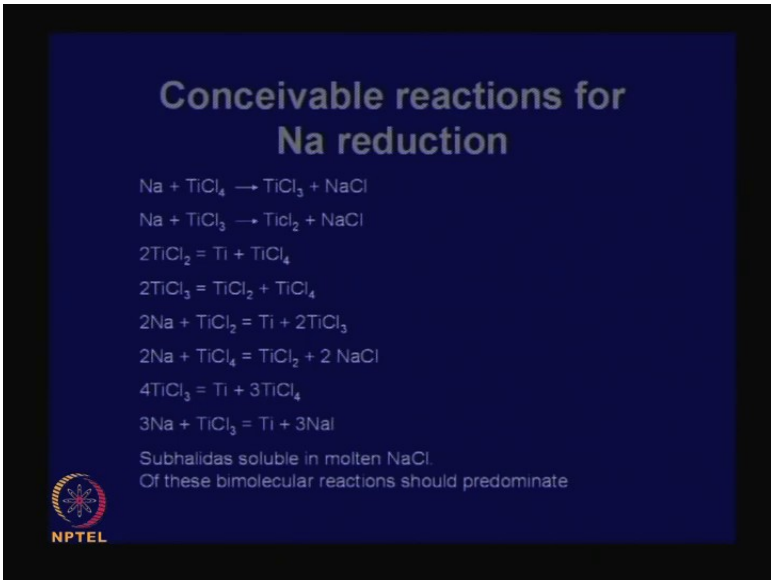

I propose that it does not occur like that. Actually, there are simpler reactions that take place. Like sodium reacts with one molecule of titanium tetrachloride, produces a sub halide such as titanium trichloride, which then dissolves in sodium chloride. Then sodium reacts with titanium trichloride, which is in the liquid state, produces another sub halide titanium dichloride and sodium chloride.

May be some sodium also dissolves to some extent in the liquid state, and reactions take place there? Now, can I give a proof that these things happen? People have found these phases in sodium chloride phase; they are transient phases, which mean they come and go.

So, the sum and substance is that the reaction of reduction of titanium tetrachloride, by sodium is not taking place in the vapor phase. It is actually taking place in the sodium chloride phase. So, there is formation of sub-halides. When we write the Penta molecular reaction, it is an overall reaction, period; that, does not give the mechanism of the reaction.

Once you understand the mechanism, which is the reaction occurring in the liquid phase, then something more interesting aspects of the reaction are coming out. We will show that later. Actually, it is an electrochemical reaction and because of the electrochemical reaction, titanium is not produced as atom-by-atom, but it is produced by an electrochemical reaction, in a much consolidated crystal form as it happens in all electrochemical processes. So, you see that just writing a reaction is not enough in process metallurgy; we have to understand the mechanism behind it. Let me proceed to another reaction.

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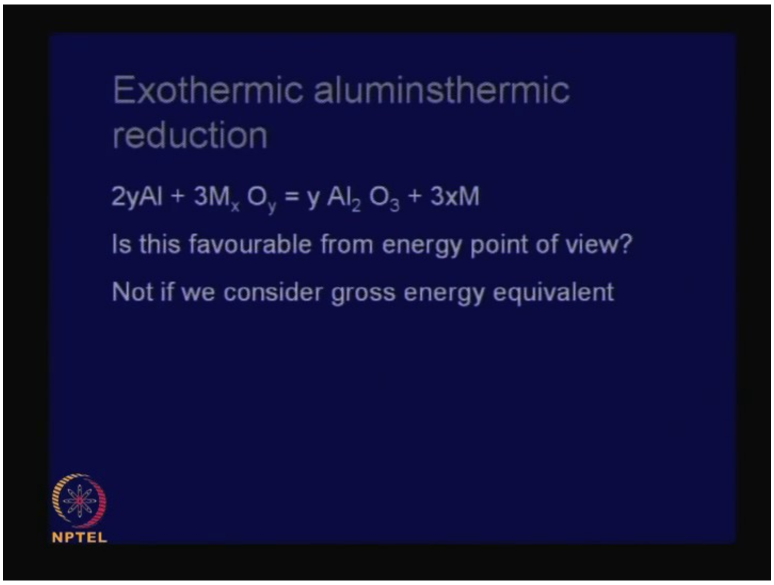

Many oxides, which we have written as MxOy, can be reduced by aluminum because aluminum forms a more stable oxide Al2O3, and it releases the metal. For example, if you can take Fe2O3 and mix with the aluminum powder, all that one has to do is simply to ignite it, and there are many methods of igniting.

(Can you write aluminum oxide and ferric oxide properly?) Request for the editor

If just a small part of the mixture gets heated to 900 degrees or so; then the reaction that proceeds is highly exothermic and then it becomes autogenous, which means you do not have to supply any more heat. It would continue, not only continue, but also, also actually sometimes become explosive because so much of heat is generated. We then might have to control the reaction, by keeping their excess of metal M, so that it can absorb some heat and control the reaction.

This kind of reaction is used in a very interesting process called, “Thermite process”. A thermite mixture is made by mixing aluminum powder and iron oxide. Sometimes it can be pure iron ore. This can be used to weld cracks in railway tracks, in rails.

If you find there is a crack, then you make a mould around it, put this mixture and simply ignite it. Reaction takes place, molten iron produce fills the gap and the rail is welded. On the spot you can do this; you do not have to bring a furnace or anything. You just need a device to ignite and there are many ways of putting the initial heat.

Now this is not the only reaction. Aluminum, as well as calcium, both of them form stable oxides and can reduce many metal oxides. Now, we might be tempted to think, that these reactions are very favorable from energy point of view because once started you do not have to supply any more heat and it goes on producing heat.

But the fact is this is a wrong way of looking at things. We are being very shortsighted. The question to be answered is, to make it energy favorable from the point of view of energy we also have to ask that question as to how much energy is required to produce aluminum, which is the reducing agent. It may so happen that aluminum needs a lot of energy to be produced.

So, if you take that energy into count, then it is not a very good process from the energy point of view. We analyze all such reactions now by using a term called, “Process Fuel Equivalent”.

We take into account all the energy that goes into production of the raw materials - input side. Then we take into account, the exothermic heat that is coming out.

We also take into account, the sensible heat of the products. May be there are gases that would come out, and from where we may be able to extract some sensible heat. All that once taken into account can be used, to define a term called “Process Fuel Equivalent”, based on which only, we can talk about energy, whether the process is favorable from point of view of energy. This process is not favorable from point of view of energy.

So, this is the way we will analyze things. Before I proceed further, let me first define what a non-ferrous metal is. Obviously, a non-ferrous metal is a metal, which is not ferrous, but one has to say little more on that.

If you look at the periodic table, which has more than 90 elements, many of them are obviously not metals, like you have inert gases. You have other gases such as nitrogen and then chlorine, bromine, fluorine; you eliminate them.

Then there are some elements, which are non-metals. Carbon for example, iodine, they may be solid and they are non-metals. If you eliminate them, then we are left with about more than 60 elements, which are considered non-metals.

You know what the definition of the metal. By metal, we normally say as something, which has a luster or call it as metallic luster, which have some mechanical properties, which is of some strength etc. Of course, there are some exceptions like mercury. Mercury is classified as a metal. It has a metallic luster, but it is not a solid. Whatever it is, there are more than 60 non-ferrous metals.

Now, we are going to talk about extraction of most of them, but not one by one. We will put them in groups, and very often, if you have understood the extraction of one or two, you can very well guess, how the other metals in that group will be extracted.

Now, we are going to take another class of alloys, which combine, ferrous and non-ferrous. These are ferroalloys. Like there are alloys, which contain iron and nickel, called as ferronickel, similarly, like ferromanganese; ferromolybdenum; ferrochromium; ferrosilicon. We will discuss on how these are also produced.

The reason is that many non-ferrous metals, which going to ferroalloys, are mostly produced as ferroalloys and not in as elemental form. There is, more demand of ferronickel than nickel, ferrochrome than chromium etc because these ferroalloys are used to add these alloying elements like nickel, chromium, vanadium, manganese into steel.

As you know, steels acquire special properties because it has non-ferrous metals in various amounts. If you want to produce stainless steel then you definitely need chromium and nickel. They will be added, to molten steel as ferroalloys, not as chromium or nickel.

So, in the industry, it is much more advantageous to produce the ferroalloy itself, which also dissolves very fast, because it has a lower melting point. So, we never add nickel or chromium in elemental form, to form ferroalloys. To form steel with these metals we add ferroalloys. So, we will discuss ferroalloys also.

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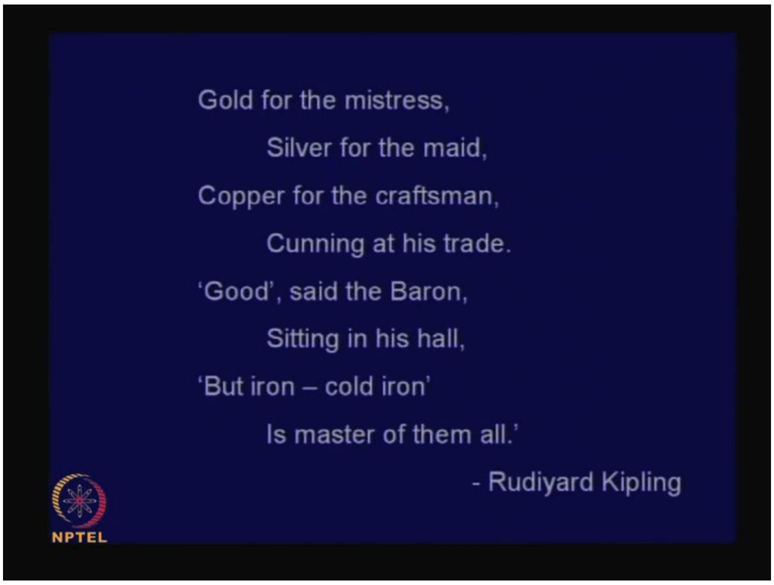

Long ago, actually in 1907 I think, Rudyard Kipling, who was the first Noble Laureate in English literature, wrote these lines. I do not know in what context he wrote these lines but I thought I should quote these lines here.

"Gold for the mistress, Silver for the maid, Copper for the craftsman, Cunning at his trade. 'Good', said the Baron, Sitting in his hall, 'But iron-cold iron' is master of them all."

Now, this poem portrays non-ferrous metals as poor cousins of iron and steel, which is not a very unfair statement. Because it is true that more than 90 percent of all metals, used today are iron and steel, that is ferrous.

But it does not mean that non-ferrous metals are not important, because there are many alloys without which, today's civilization simply cannot exist and there you need non-ferrous metals. To start with, think of the airplanes and the spacecraft's, which are based on aluminum and titanium, because these metals are light and strong.

We cannot make airplanes out of steel or we cannot make aircrafts and spacecrafts out of steel. There you need titanium, aluminum and also some other elements. In electrical applications, we need copper, because copper is a very good conductor of electricity. Silver is even better conductor, but you know silver is expensive, so cannot have silver wires, but there are some critical contacts in electrical contacts where silver is to be used.

Similarly, all metals have very critical applications, and we will come to their uses, when we talk about them. Precious metals like gold, silver, platinum, palladium are very good for making ornaments, Of course, these days people are making ornaments out of steel also. But you know women would rather have gold and silver, than steel to wear around their necks.

But these precious metals make fantastic catalysts for critical reactions, especially platinum and palladium and there are other reasons. Though iron and steel are the basis of our civilization, still we need to have these precious metals.

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Now, to show you the importance of iron and steel visa a Vis non-ferrous metals, let me just say that today the world produces 1350 million tons of steel. This is a more than 1000 million tons, of which India produces 40 million tons or so, which is about one-thirtieth or one-twenty-fifth.

Next comes aluminum, whose world production is, around 40 million tons only. So, in steel you have 1350 million tons, next you have aluminum, which is 40 million tons, of which India produces 135000 today, in year 2009.

But then it is a big improvement from 1980, when the figure was a quarter of a million. So, in the last 30 years, we have grown; say by five times. It is not much of a growth and I think China is way ahead of us. Aluminum is one sector in which India can grow because India has very good aluminum ores. The problem is we do not have power, which one needs for aluminum extraction.

So, India is trying to go to other countries like Vietnam or Dubai, where power is cheap. India has the knowhow and human resources, so they are trying to go and open up plants but it has to come up in India also.

Look at the other elements such as copper; it has grown tremendously from 50000 in 1980 or so to 65000t today. Zinc has gone from 100000 to 585000. Cadmium, which is a byproduct of zinc, is produced in large amounts today. Lead production also gone up from 35000 to 61000.

The problem with copper, zinc and lead is that in India the ores are very limited. But if once you have the knowhow, we can always import the concentrates and produce them in India, which some companies are doing already.

All I can say is that we have a long way to g, in non-ferrous metals production. India has a fantastic history to which I will refer to, little later. Our present is not bad but I think our future has to be much brighter.

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This is just to repeat that the world production of aluminum is about 40 million tons per year and that of steel is 1350 million tons per year.

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Now, let me come to the learning objectives of the first module, where I am talking about the history of metals. First is to discuss past, present and future of non-ferrous metals production in India. Then it is to discuss fundamental principles, I am talking about the learning objectives of the course.

To discuss past, present, and future of non-ferrous metal production in India, to discuss fundamental principles of extraction and refining of non-ferrous metals, to understand applications of thermodynamics and kinetics, to discuss extraction of groups of metals according to modes of occurrence of nature of main starting compounds and then to discuss energy in environment related issues in metal production.

We will consider issues of energy and environment whenever we will talk about a metal or a group of metals. I will discuss the, with lot more emphasis later in the course. Because today, anything we do, we have to keep in background the environmental angle and the energy angle

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We start the course, with a brief history of non-ferrous metal production in India, and some of the remarkable achievements in the past. I do not know how many of you are aware that India has had a very rich tradition in metal production, non-ferrous metal production, as well as production of iron steel.

Unfortunately, we are very good in forgetting our past, and we have forgotten everything. Until in the nineteenth century, some British historians started to dig out something about our past. They were there scattered in the literature here and there. But of course, the British did a very thorough research. You may have heard about William Jones. There was also a Colonel Todd, who wrote a history of Rajasthan and many of the early metal activities where in Rajasthan area, I would come to that.

I do not know whether you are aware, that India had forgotten Asoka also, and until seventeenth or eighteenth century, nobody ever talked about Emperor Asoka. People had remembered Buddha, because the Buddhist has maintained a tradition. Asoka was forgotten. It is only the Britishers, who found in inscription of some pillars, monuments and stupas, repeatedly referring to somebody called Priyadarshi.

That word Priyadarshi came again, and again, and they started asking the question, who is this Priyadarshi, who says he has erected these monuments, these stupas?, Who is giving instructions? Then they finally, found this Priyadarshi was no other than Emperor Asoka, who either assumed the title or people gave him that title.

You know Priyadarshi, means 'good to look at'. Some say it also means one who looks at others affectionately, because he always considers things beneficial to his subjects. Just imagine, we had forgotten Asok! So no wonder that we have forgotten many other things also

But now, a lot of research is being done, and in last 50 years or so, many papers have been written, books have been written.

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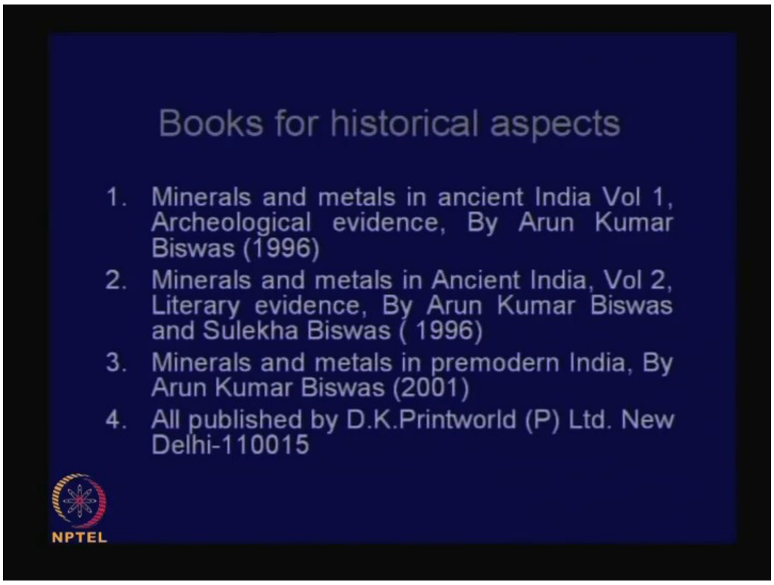

And I am going to give you some information collected from these three books. All written by professor A K Biswas, who was a very dear colleague of mine in IIT- Kanpur. He is a great name in mineral beneficiation area, but he also written some fantastic books in the area of archeometallurgy. All are published by D.K. Print world limited and are very highly acknowledging.

One is the, "Minerals and metals in ancient India, volume one, Archeological evidence". The other one is, "Minerals and metals in ancient India, volume two", which he wrote in collaboration with his wife Sulekha Biswas, who is a scholar in Sanskrit. She could read and translate old Sanskrit's scripts. Third is, "Minerals and metals in pre-modern India", which means the period just before the Britishers , It discusses the period middle ages to the coming of Britishers.

So, I have collected some information from these books, which I would like to share with you. See, there is evidence of our rich past and this has been given in the books that I have just mentioned. Let me talk about iron and steel first, because that is also important even though this course is about non-ferrous metals. . There is evidence that India had

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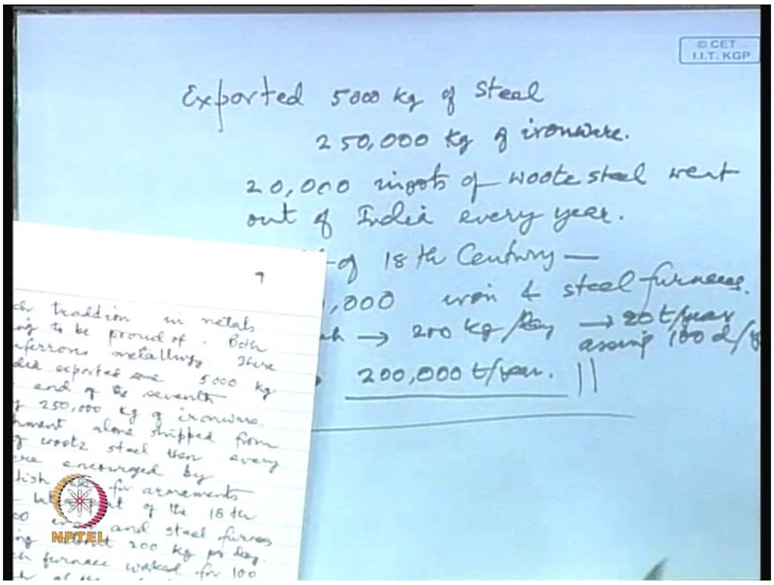

Exported 5000 kg of steel towards the end of the seventh century. Nearly, 250000 kg of iron, ironware. At that time there was a Dutch establishment in India, the Dutch establishment have left records that 20000 ingots of Woods steel went out of India every year.

In the later part of the eighteenth century, this is close now. Remember, there were 10000 iron and steel furnaces, all over India, each producing 200 kg per day. Most of them were done by tribal and they were in forest areas. So, India was producing a lot of iron. Each of them produced 20 tons per year, assuming 100 working days per year. So, India was producing easily 200,000 tons per year of iron steel.

This continued until eighteenth century and then it declined and the decline was obviously for two reasons. Firstly, the Britishers did not want the local iron and steel manufacture and they were importing much cheaper steel from England. Secondly, all the indigenous production was based on charcoal. For centuries, India used charcoal to produce iron, and charcoal was becoming more expensive. India never went in the coal route-- that the coal to produce coke and use that to reduce iron ore. It was always charcoal based. That is why we made very special sponge iron; very pure sponge iron, and we have examples of the iron pillar of Delhi which is still existing.

So, India had a thriving iron and steel industry, but it had to die. It died a natural death, I would say. Incidentally, the first iron works of India that came up was ISCO, at. Bhadravathi. You have heard about Visweswaraya, the great engineer. He established the plant at Bhadravathi that was also initially charcoal based. The idea was that they would use forest and they will re-grow trees. But, of course, that could not be sustained. So that has gone out now.

So, this was the iron and steel scenario. About the non-ferrous metals, I will come little later as to where did India stand.

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Now let us talk briefly about the history of metals and then, you will know how things have come after another. Until about 7000 years ago, which is that is up to about 5000 B.C, we had the period called Paleolithic age or Old Stone Age.

Old Stone Age was when men were hunting and gathering food from forests, they had not settled down. The settlement started around 5000 B.C and we said that was the beginning of the New Stone Age or Neolithic Age.

Lethos means stone. Humans learned the art of farming and domestication of animals.

Now, once humans learnt that they could grow plants to grow food, and they did not have to run around after wild animals. They could actually have some animals at one place, which will multiply. Then they could stay at one place, so the settlements began to appear; that was the New Stone Age.

Then they learnt to use the fire, to produce baked potter and, cook food. These are all the distinctive features of a new stone age. There was no metal in the scene at that time.

Around 3500 B.C, there was the beginning of ancient civilization in Egypt, Mesopotamia and Indus valley more or less of the same time. Although, we say the first civilization came in Mesopotamia, which is today Iraq.

So, our Indus valley civilization which we call Harappa and Mohenjo-Daro, that covered the north east of India, that covered what it present day Pakistan, and Mohenjo-Daro is today in Pakistan. I will show you the area.

There is a reason why the developments took place in that north-west of India, because it was close to the Middle East, central Asia. So, that is where things were happening, and there was cross fertilization of ideas, migration of people. We have heard that actually Aryans came from central Asia. Some people say, it is a wrong theory and there is lot of evidence to say it did not happen. There was no such thing; may be people went from here to there or people were always here.

So, I would not go into those theories but it is true that it was almost simultaneous; Egypt, Mesopotamia, Indus valley and China also, China also had the beginning of metallurgy more or less at the same time.

But the Harappa civilization of India, was a very vast area covered, and I will give you some maps to show that how largely extended it was, and it went on for many centuries also.

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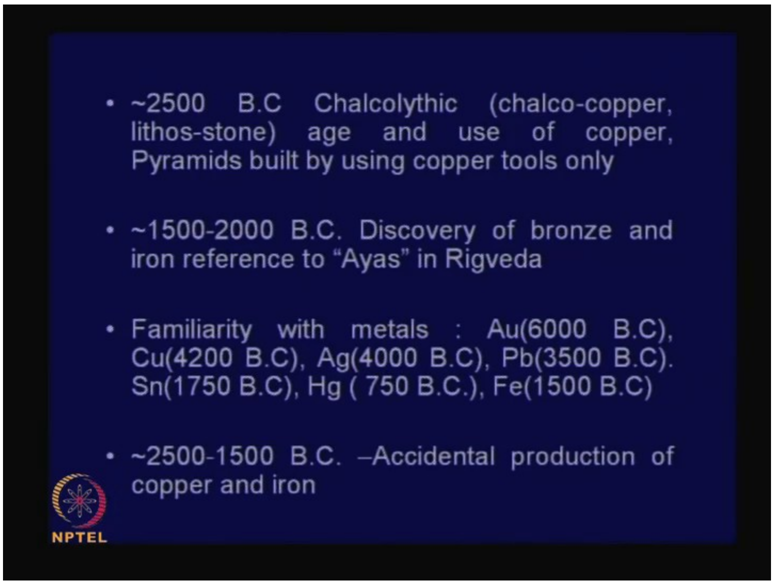

The earliest reference to metals in India, of course, is in the Rig-Veda. But before that, let me go back to this Chalcolithic period. I have talked to you about the Neolithic period when people were using stone, then comes the Chalcolythic period . "Chalcos", means copper and "Lithos", means stone, means they found copper. How they found copper, I will come to that later.

Firstly, copper can be found in nature, sometimes in a native state, and some people must had found that. So, they were beginning to make tools or implements or weapons using not only stone but also copper. The pyramids were built in entirely by using copper implements, which is rather strange! A huge structure, built with only tools made of copper. There is reference in the history that the Ramses II went and attacked Hittites. Hittites were another civilization slightly towards the northeast. Hittites had by that time got iron ore weapons but the Egyptian did not have. It was a draw; nobody really won in that war.

But the Egyptians did not have iron then and you should know that Iron came much later., In between we had the bronze age, about 1500 to 2000 B.C, when there was discovery of tin mixed with copper to produce bronze which actually is a very strong metal- strong alloy, which is also corrosion resistant.

Many people say that there was no reason why steel would replace bronze, because in many things bronze is as good as steel, if not better, especially in terms of strength.

The only reason that steel became much more popular and more common is simply because there is much more iron ore available. Lot more steel was produced and the cheaper than bronze, otherwise bronze was an excellent alloy at that time.

Now, in India, the first reference to metals is found in Rig-Veda. Rig-Veda, of course, is the first literature of ancient India (Refer Slide Time: 44:01). It was not written down, but you know it went from mouth to mouth. This Rig-Veda was composed, when there was a transition between this New Stone Age and Chalcolythic period. -- means people who are still hunters gatherers, they are settling down and beginning to use metals. There is a word called "Ayas" in Rig-Veda that is mentioned very frequently and some people think that the word "Ayas", means iron.

But it is been argued by Arun Biswas and others, that actually Ayas should not mean iron. It really means metal, because they are references in Rig-Veda, saying Black Ayas and Red Ayas. One means iron and the other means copper. So, this could also mean the bronze. Where did iron come from? Iron actually came because; from these skies, sometimes meteoroids fall to ground, and that is almost pure iron. So, our ancients had found native iron here and there, and they have found that superior metal.

So, the familiarity with iron had come like that. Of course, there was always familiarity with gold and silver. Because gold is available in the native state very often and that they were small amounts of gold that could be collected from rivers which carried gold particles. Or they have found gold exposed on rock surfaces. You know, in South America and there were tons of gold that the Spanish collected.

So gold was also known pretty early to humans. Now, as you consider familiarity with metals Gold was, perhaps, the first that humans collected. How do you know this? Because there are many ancient graves where explorers have found gold along with many things-- there were gold ornaments, of course, a very crude sort of thing but there was gold.

Then came copper and silver a little later, because silver had to be separated from gold. Silver is always with gold. Then came lead, tin, mercury and iron. Why they come one after another? I will discuss little later. There is a very interesting story as to how the first copper was produced.

It is believed that copper was first discovered in Egypt where they used an ore called Malachite as eye shadow.

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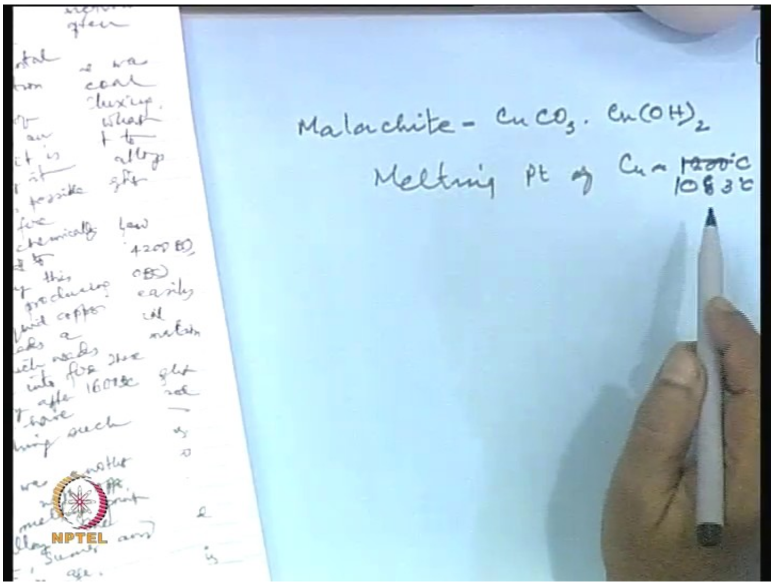

Queen Cleopatra and all would use this black ore around their eyes. You should know that what you see t in pictures is Malachite.

The ore containing this mineral, is found in plenty in Egypt and what may have happened is this. During some rituals, apparently it fell into fire. In the fire, it got reduced, because in the fire, it was broken into copper oxides, then there was carbon there which reduced the oxides into copper. Once they found that this was a new material, they learnt by trial and error to produce large quantities we believe that is how a copper production started.

There is something interesting though, because the melting point of copper is almost 1200 degrees, It is not easy, to get 1200 degrees, because 1200 degrees normally needs bellows, like you put a fire it will go up to 900 and 1000, and then if you blow air by using bellows, then the temperature will go up further.. Somehow, they had found a way to do this. I do not know how they found it. .

Now, I think I made a mistake, the melting point to copper, sorry, is not 1200. It is actually near 1100; actually the melting point is 1083 –yes ten thousand and eighty three.

But to make the process happen, you need to go slightly higher temperatures, which needs bellows, and this bellows they had found. The Egyptians found some way of getting to the temperature 1100 or 1200 degrees and they were making copper.

How did they make bronze? Perhaps there was some ore where there was already some tin, and tin got reduced, got mixed up with copper that is how bronze came?

You know that ores are seldom pure minerals. They are always mixtures of minerals and all kinds of impurities, called gangue. And sulphides are particularly known to dissolve all kinds of things, and that is how, we seldom get copper, lead, zinc in the form of pure minerals or pure ores. They are always mixed together. Of course, the compositions vary from one location to other.

So, when they were trying to produce copper, sometimes they ended up producing tin. Sometimes they ended up having other metals also, produced other alloy. But gradually they learned as to which ore from which location will produce what.

People did not very clearly knew the distinction between one metal another metal or another alloy, but they were beginning to use copper and bronze quite extensively in the beginning. There was no zinc in this scene and I will come, I will discuss that later.

Around 2500 to 1500 B.C, there was accidental production of copper and there was accidental production of iron. Now, about accidental production of iron, I would come in when I continue this lecture in next hour.

So, what I have done so far is this. Let me conclude. I have tried to give you an introduction by talking about the importance of non-ferrous metals. To tell you that the state of non-ferrous metal production in our country today is not unsatisfactory, but we have a long way to go. We have had a history in non-ferrous metal production to which we I still have not come and now I will discuss it in the next time, but this is a course, you simply cannot ignore. To be a metallurgist, you have to know about iron steel production, you also have to know about non-ferrous metal production. So, let me stop here now, and I will continue with you in the next class. Thank you.