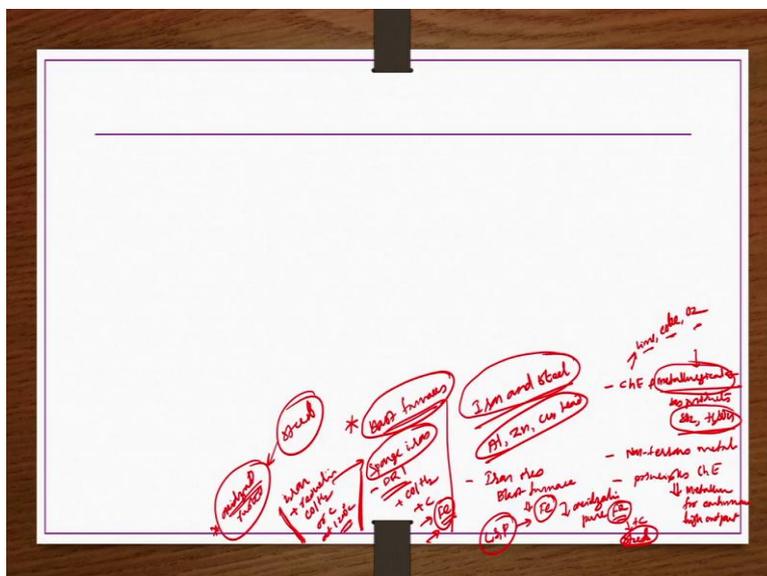


**Inorganic Chemical Technology**  
**Prof. Nanda Kishore**  
**Department of Chemical Engineering**  
**Indian Institute of Technology, Guwahati**

**Lecture - 35**  
**Metallurgical Industries - II**

Welcome to the MOOCs course Inorganic Chemical Technology, the title of today's lecture is Metallurgical Industries, part 2. Before going into the details of today's lecture, we will have a recapitulation of what we have discussed in the previous lecture.

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We have started our introduction with a connection between chemical engineering and then metallurgical engineering or chemical industries versus metallurgical industries. So, then why we started looking at the connection because this course is inorganic chemical technology, then why do we need to study about metallurgical industries.

So, then what we realized that whatever the not all, but many of the products that chemical industries produce like lime, coke, oxygen etcetera are being utilized by these metallurgical industries for different types of processes, which occur in metallurgical industries right. Something like iron making, steel making. So, there we are using this coke etcetera, oxygen etcetera that we are using, right.

Similarly, like metallurgical industry is not only a consumer of chemical products, but also byproducts of these metallurgical industries something like you know sulfur dioxide,  $H_2SO_4$  from the ZNS smelting process or copper smelting process etcetera are you know kind of good products of chemical plants, right.

So, these byproducts of these plants or byproducts of metallurgical industries are a proper chemical plant products like  $H_2SO_4$  etcetera. So, there is a connection, right. Similarly, like you know several types of nonferrous metals are used for different types of applications household, domestic industrial purposes etcetera.

Also, whatever the principles of a chemical engineering are there they are being increasingly utilized for a metallurgical industries for a continuous process so, that to improve the high output of the metallurgical industries. So, because of such kind of connections it is essential to know for a undergraduate UG level students a few basics about metallurgical industries.

So, then we started discussing about metallurgical industries out of which we have taken different types of metallurgical products like iron and steel and then nonferrous metals like you know aluminum, zinc, copper and then lead etcetera these kind of products they are manufacturing we are going to study.

So, in the previous lecture we have already discussed about manufacturing of iron. So, iron we got it from the iron ores, where iron ores along with the coke, lime etcetera have been taken into a blast furnace where the reduction of these ores takes place and then you get a iron pig iron, right.

This would be further oxidized to get a pure iron because whatever the iron that you get from the blast furnace it may be having impurities like you know sulphur, phosphorus, carbon etcetera. So, these impurities you have to remove how do we remove them by oxidizing by oxidizing this molten pig iron you can remove oxides of the sulphur, phosphorus etcetera and then you can get the pure iron.

So, but pure iron we found that it is of no use because it is soft in nature as well as its melting point is very high. So, then what you do you have to do proper alloying with the carbon to get the steel. So, these alloying etcetera can be done in you know electric furnaces those things we have seen.

Then we have also discussed about the sponge iron which is nothing but directly reduced iron or obtained by direct reduction of iron whatever the hematite or magnetite ore is there that if you react with a CO or H<sub>2</sub> or carbon then what will happen you will get a iron right, which is sponge iron which is having purity of approximately 90 to 94 percent similar like you know pig iron, right.

So, iron content of this sponge iron is about 90 to 94 percent which is on par with the pig iron, but it is having several disadvantages as well though the advantage of this production of sponge iron by DRA method or Direct Reduction Method is that you know avoiding the complications of a blast furnaces blast furnaces are having several complications especially from the design and then operating conditions point of view.

So, those you can avoid if you do this sponge iron production by direct reduction of iron ores. How you do it? Because this you do you know you take the iron ores and then you do the reduction either using CO, H<sub>2</sub> or C, but at lower temperature like something less than 1200 degree centigrade something like that. So, that melting of ore is not required.

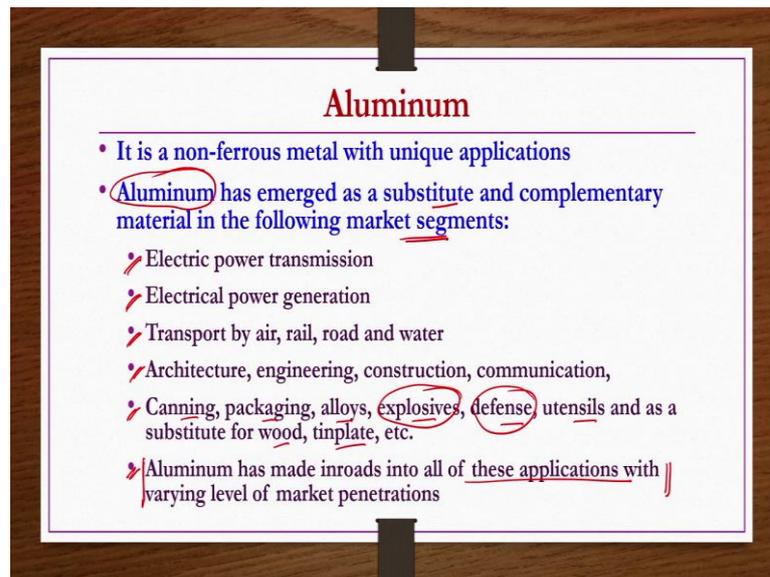
So, if the melting of ore is not required. So, then obviously, you can avoid using blast furnaces etcetera. So, that is the advantage it is having right further the whatever the heat evaluated because of this direct reduction of iron ore to get sponge iron. So, that heat may be utilized in further alloying purpose as well.

So, that those two are advantage of this sponge iron or you know DRA production by direct reduction, but disadvantage it is very it get oxidized sponge iron easily get oxidized or it will be rusted or corroded if you do not protect properly. So, these are the kind of disadvantages also there.

So, sponge iron from the production point of view it is having advantage of not using blast furnace or getting away with the complications of blast furnace, but it is having the disadvantages of getting easily oxidized or rusted if not protected that is the reason if not protected.

That is the reason this sponge iron whatever is produced that is directly or quickly utilized to produce the steel by doing proper alloying with the carbon. So, this is what we have seen in the previous lecture, in this lecture we are going to discuss about non ferrous metals production how it is being done in metallurgical industries.

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So, let us start today's discussion on non-ferrous metals production we start with aluminum. It is non-ferrous metal with unique applications what are the applications if you see aluminum has a must has a substitute and complementary material in the several of market segments some of them are presented here.

So, like in electric power transmissions electrical power generations transport by air, rail, road and water then architecture engineering construction communication market this aluminum is used not only for that for canning packaging alloys explosives, defense utensils as substitute for wood and then tinplates etcetera also this aluminum is used. It is having so many applications so many applications both domestic, industrial and then including the defense purpose as well like in explosives also it is used, right.

So, because of that one you can see that market for aluminum is very huge though it is not a direct market, but indirect market it is having applications or utilization in several of these market segments. So, its production is going to be a very beneficial for the growth of a any country, ok.

So, aluminum has made inroads into all of these applications with varying level of market penetrations because. So, it is not like that 90 percent is used in one electric power generations only and then remaining 10 percent is used for other purpose it is not like that varying proportions are there and then depending on the need you know the proportions changes, ok.

How much aluminum is required for a given market or for a given production purpose of any of these you know material that are mentioned so, you know the changes from application to the applications, right. So, now this aluminum production is not possible to directly produce from the bauxite ore actually bauxite ore is used to produce alumina or aluminum oxide which is  $Al_2O_3$  that  $Al_2O_3$  would be further you know reduced in electrolytic cells to get the aluminum metal, ok.

So, first what we have to do we have to understand the process to get alumina or aluminum oxide from the bauxite ore and then using that alumina for the production of aluminum metal.

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$Al_2O_3$  production as raw material for aluminum manufacture ↓ electrolytic cell

- Major source of aluminum oxide or alumina used in electrolytic reduction cells is bauxite
- It is a 50 – 60%  $Al_2O_3$  ore with balance as silica and iron ore
- Purification process for electrolytic cell-grade alumina is discussed here first
- Chemical reactions:
  - (a)  $6NaOH(aq) + Al_2O_3(s) \rightarrow 2Na_3AlO_3 + H_2O$
  - (b)  $Na_3AlO_3 + 3H_2O \rightarrow 3NaOH + Al(OH)_3$
  - (c)  $2Al(OH)_3 \rightarrow Al_2O_3(purified) + 3H_2O$
- Raw materials:
  - Bauxite is major
  - Minor quantities of make-up NaOH

So, let us start with production of  $Al_2O_3$  which is a raw material for production of aluminum. So, directly aluminum production is not possible in fact, this aluminum production is done by the electrolytic cell approach, right.

So, that is a different process whereas,  $Al_2O_3$  production is more or less like any of the inorganic chemical production that we have seen that is size reduction of the ore purification of the ore reaction of the ore and then separation of the product something like those kind of steps. So, all those things we are going to see now.

So, how to get this  $Al_2O_3$  so, what is the raw material for this  $Al_2O_3$  production it is nothing but the bauxite major source of aluminum oxide or alumina, which is used in

electrolytic reduction cells is bauxite. So, this bauxite is used to get aluminum oxide or alumina which would be used in electrolytic reduction cells to get aluminum metal, ok.

So, this bauxite usually contains 50 to 60 percent of  $Al_2O_3$  ore with the balance of silica and iron. Purification process for electrolytic cell grade alumina is described here first. First you have to get the alumina and then alumina of which grade it should have a higher grade so, that it can be treated in electrolytic cells to get the aluminum metal, ok.

So, first we do the purification actually this bauxite ore you take and then do certain unit operations to get purified alumina, ok. So, how to get that purified alumina, which can be used in electrolytic cells to produce aluminum that is what we are going to start with. So, first we start with the purification of alumina then we go to the electrolytic cell reduction for the production of aluminum.

If you see the chemical reactions for purification of  $Al_2O_3$  or bauxite ore it is nothing but whatever  $Al_2O_3$  in the solid form that is present in the ore that part of bauxite or you know  $Al_2O_3$  part of the bauxite ore would be reacting with the sodium hydroxide to give sodium aluminates that sodium aluminate will further react with water to give sodium hydroxide and then aluminum hydroxide.

This aluminum hydroxide will further dissociate into  $Al_2O_3$  which is purified  $Al_2O_3$  plus water. So, this  $Al_2O_3$  is the purified one whereas, this  $Al_2O_3$  in the reaction A is there that is whatever the 50 to 60 percent of you know  $Al_2O_3$  that is present in bauxite ore is there that is represented by this, ok.

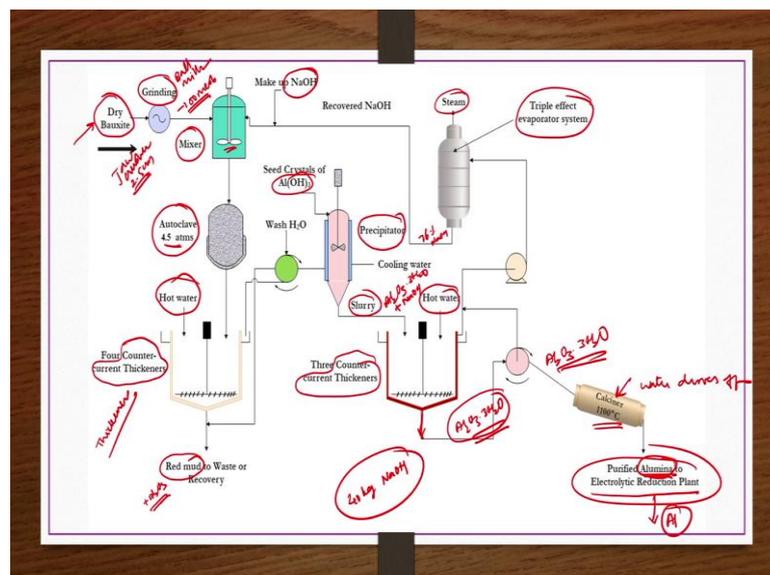
There may be some other side reactions may also be there let us not worry about that one these are the primary reaction that are occurring in order to purify  $Al_2O_3$  from the bauxite ore. Raw materials obviously, now you understand that bauxite is raw material and then make up caustic solution NaOH is also required. So, bauxite is major one, but minor quantities of makeup NaOH is also required.

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- Quantitative requirements:
- (a) Basis: 1 ton of  $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ 
  - Bauxite (50 – 60 %  $\text{Al}_2\text{O}_3$ ): 1.3 tons
  - NaOH makeup (76% caustic): 40 kg
  - Water: 24 tons
  - Steam: 6 tons
  - Power: 160 kWh
- (b) Plant capacities: 50 – 200 tons/day

Quantitative requirements if you see basis if you wanted to produce one ton of trihydrated alumina right that is  $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$  then bauxite ore containing 50 to 60 percent  $\text{Al}_2\text{O}_3$  you need 1.3 tons NaOH make up solution which is 76 percent purity 40 kgs is required then water is required 24 tons steam 6 tons required power 160 kilowatt hours required plant capacity usually 50 to 200 tons per day.

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Now, we see the flow chart of a alumina purification process, ok. So, for this process what you do dry bauxite whatever you get from the mines from the natural resources

whatever the natural resources you do the mining and then you get the bauxite ore which is in dry form. So, that you do the crushing of that one by jaw crusher to 2 to 5 centimeters roughly then that crushed material is taken to grinders usually ball mills in this one wet grinding is done.

So, that to reduce the size of the material to minus 100 mesh size whatever size reduced to minus 100 mesh size ore is there that along with the makeup NaOH is taken in a mixer, where both of them are mixed. And then this mixture is taken to a autoclave which is operating at 4.5 atmosphere where proper reaction takes place and then you get the sodium aluminates, right. So, this mixture is further taken to a series of counter current thickness.

Counter current thickness now you must be understanding what is happening in thickness by this time already. Thickness here you separate the material based on the density or size right primarily now here we are doing based on the density. So, here you do not have one single thickener you may be having 3, 4 thickness etcetera depending on the size of the plant and the depending on the how much material are you considering for the purification.

So, in a series of thickeners this mixture that is coming from the autoclave which is operated at 4.5 atmosphere that is you know from which you are getting mostly aluminates sodium aluminates you are getting. So, those things you take in series of counter current thickness to which hot water is added.

So, that here whatever the red mud impurities are there they will be recovered. This red mud may also be having some kind of alumina contents as well. So, then what you do you cannot throw them as it is. So, then it is better to recover them. So, how do you recover? You know you can react with the silicates etcetera and then you can get the sodium silicates etcetera and then further processing you can do.

Whereas, the overflow of this series of counter current thickness are there they are nothing but the sodium aluminates those would be diluted that slurry would be diluted with additional wash water and then that mixture is taken to a precipitator where selective crystallization of trihydrated alumina will take place because of you know addition of this alumina hydroxide crystals as well to this one.

So, whatever the slurry that is coming out from this crystallization unit that is having primarily trihydrated alumina plus NaOH solution only. So, this slurry is further taken to a series of counter current thickeners to which hot water is supplied. The purpose of this second set of thickeners is to recover NaOH from the trihydrated alumina.

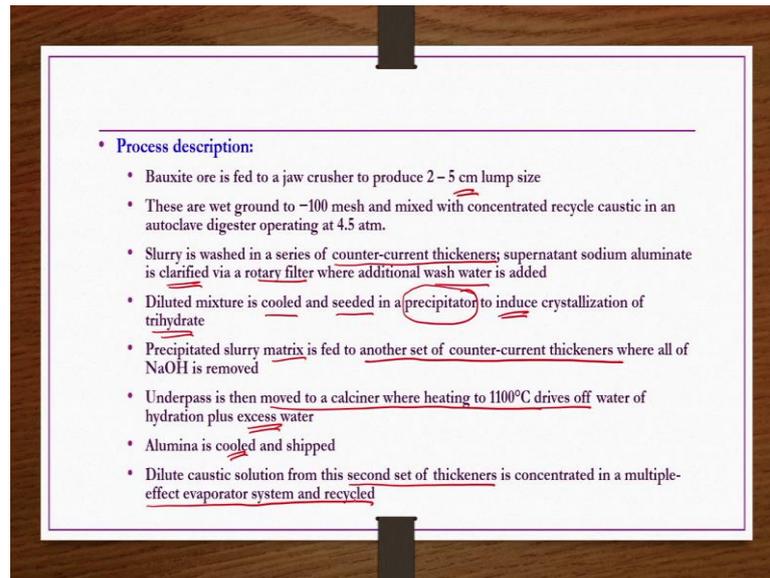
So, that recovered sodium hydroxide whatever is there that would be concentrated in a triple effect evaporator using steam and then concentrated sodium hydroxide once its concentration reaches to the 76 percent or more that would be taken to the mixture along with the makeup NaOH. So, that you know you do not need to use too much of NaOH the same NaOH can be recycled for the entire process that is a reason in this case you know you need only 40 kgs of NaOH because you are recovering and then reusing it, ok.

Whereas, the slurry that is coming out of this you know from the bottom of this counter current thickeners second set of counter current thickeners would be you know having only  $AL_2O_3 \cdot 3H_2O$  that is trihydrated alumina only. These crystals of  $AL_2O_3 \cdot 3H_2O$  would be passed through a rotary filter.

So, that to recover if at all NaOH still is present. So, that NaOH would be again mixed with the you know recovered NaOH and then sent to the triple effect evaporator for further purification. Whereas, the almost pure  $AL_2O_3 \cdot 3H_2O$  whatever is there that would be taken to a calciner where the temperature is maintained at 1100 degree centigrade.

So, that water etcetera drives off and then you have purified alumina only. This purified alumina is of certain high grade. So, that it can be directly used in electrolytic reduction plant to get aluminum metal, ok. So, whatever the process we have seen in this flow chart the same thing we are going to see by description now.

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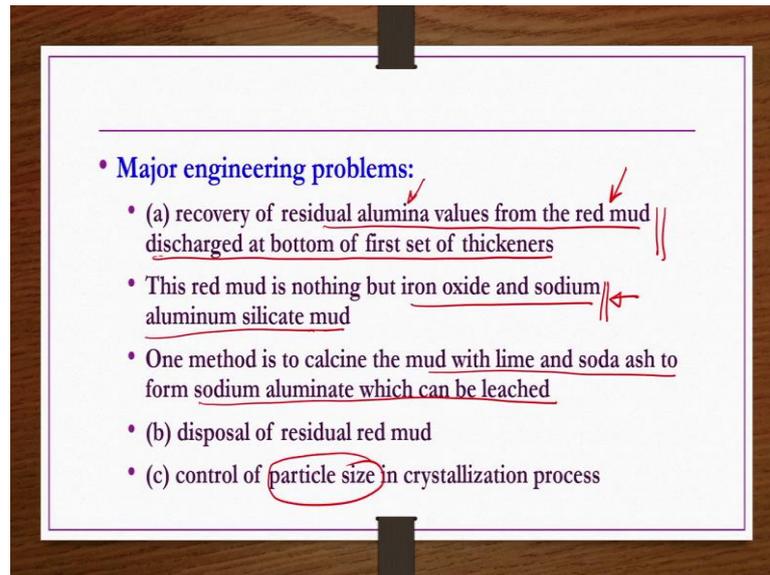


Process description: Bauxite ore is fed to a jaw crusher to produce 2 to 5 centimeter lump size. These are wet ground to minus 100 mesh size and mixed with concentrated recycle caustic in an autoclave digester operating at 4.5 atmosphere. Slurry is washed in a series of counter current thickeners supernatant sodium aluminate is clarified via a rotary filter where additional wash water is added diluted mixture is cooled and seeded in a precipitator to induced crystallization of trihydrate or alumina trihydrate.

Precipitator slurry matrix is fed to another set of counter current thickeners where all of NaOH is removed. Underpass is then moved to a calciner where heating to 1100 degree centigrade, drives off water of hydration plus any excess water that is present. So, that you get pure dry  $Al_2O_3$ .

Alumina is then cooled and shipped. Dilute caustic solution from this second set of thickeners is concentrated in a multiple effect evaporator system and recycled. So, this is about the process. What are the possible major engineering problems in this alumina purification process?

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Recovery of residual alumina values from the red mud discharged at bottom of first set of thickeners is very much essential because whatever the red mud as I mentioned you cannot throw directly you cannot discard because the thickeners process are not so effective that it completely separates the red mud from the sodium aluminates, right.

So, that red mud may also be having some amount of alumina. So, you have to recover them. So, that recover is one of the important problem. This red mud is nothing but iron oxide and sodium aluminum silicate mud right. So, then obviously, because of their contents you have to recover them not only recovering, discharging after recovering of this alumina etcetera from the red mud, discharging of red mud is also an issue.

One method is to calcine the mud with lime and soda ash to form sodium aluminate which can be leached and then another problem is the disposal of residual red mud. Then further is that control of particle size in crystallization process is another issue that one should be careful.

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**Aluminum**

- **Chemical Reactions:**
  - (a)  $2 \text{Al}_2\text{O}_3(\text{s}) + 3 \text{C}(\text{s}) \rightarrow 4 \text{Al}(\text{l}) + 3 \text{CO}_2(\text{g}); \Delta H = +470 \text{ kcal}$
  - (b)  $\text{C} + \text{CO}_2 \rightarrow 2 \text{CO}$
- **Raw materials:**
  - Purified bauxite as discussed in previous flowchart
  - Electrode materials (coke, pitch and tar)
  - Cryolite flux ( $\text{AlF}_3 \cdot 3\text{NaF}$ )

So, that is what we have seen. So, we have seen how to purify  $\text{Al}_2\text{O}_3$  from the bauxite ore we have seen and then not only purification to a grade. So, that it can be used in electrolytic reduction cell to produce aluminum to that level we have seen. So, now what we are going to see we are taking this one as raw material alumina or purified alumina that we have seen how to produce just now that will take as input or raw material to get aluminum metal, ok.

So, aluminum chemical reactions obviously, it is between alumina purified alumina this is not the bauxite ore alumina it is a purified alumina reacts with the carbon to give aluminum and then carbon dioxide, other reaction is that carbon reacts with carbon dioxide to give carbon monoxide.

Raw materials obviously, purified bauxite as discussed just now plus electrode materials are made by coke pitch and tar either they are continuously managed or you know periodically they are replaced. So, electrode consumption is more because this reactions are taking place at the electrodes and then see carbon of those electrodes is being consumed to get the aluminum ok. The flux that is cryolite flux is also required which is nothing but  $\text{AlF}_3 \cdot 3\text{NaF}$ .

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The slide contains the following text:

- **Quantitative requirements:**
- (a) **Basis: 1 ton of aluminum**
  - Alumina (99%  $\text{Al}_2\text{O}_3$ ): 2.25 tons
  - Coke: 0.5 – 0.6 ton
  - Tar and pitch: 20 – 30 kg
  - Cryolite: 40 kg
  - Electricity (DC): 22,000 kWh
- **Electrolytic cell designation:**
  - $\text{C} \mid \text{Al}_2\text{O}_3 \cdot \text{AlF}_3 \cdot 3\text{NaF} \mid \text{Al(l)} \mid \text{C}; E_r = 2.8 \text{ volts}$

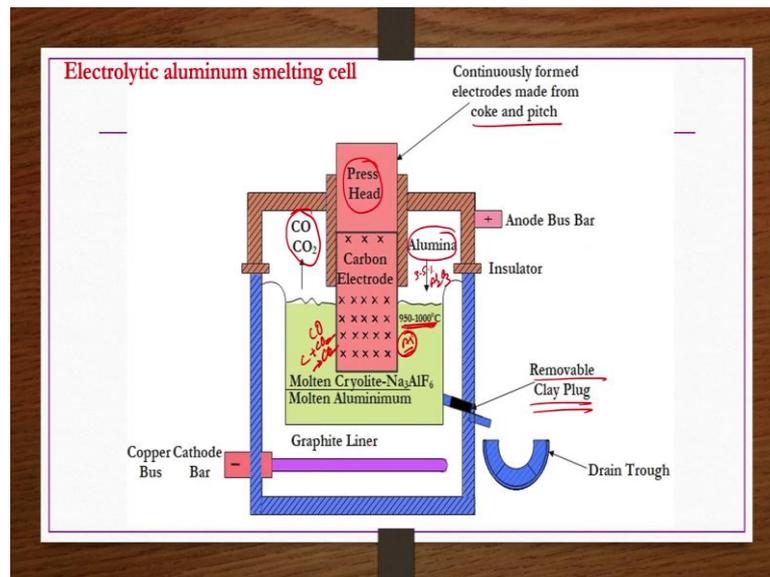
The diagram shows a dashed arrow pointing from the anode (+) to the cathode (-). The anode is labeled "Anode" and the cathode is labeled "cathode".

If you see the quantitative requirements for the production of aluminum from the purified alumina if you wanted to produce 1 ton of aluminum then 99 percentpure  $\text{Al}_2\text{O}_3$  you required 2.25 tons coke you required 0.5 to 0.6 tons these reactions are taking place at electrode surfaces that electrodes are being consumed.

So, in order to make up the electrodes continuously or you know periodically replace those electrodes you need you know new electrodes, right. So, these electrodes are made up of tar and pitch for that you need 20 to 30 kgs of tar and pitch. Cryolite flux you required 40 kgs and then electricity direct current 22000 kilowatt hours required.

So, any electrolytic cell reaction representation is important. So, electrolytic cell representation is provided here at the anode you have  $\text{Al}_2\text{O}_3 \cdot \text{AlF}_3 \cdot 3\text{NaF}$  at which the reaction with the electrodes takes place where  $\text{Al}_2\text{O}_3$  reacts with the electrode material to produce aluminum in the liquid form. So, that aluminum passes towards the cathode, right. The volts of this reaction is nothing but 2.8 volts, ok. This is the representation of the electrolytic cell.

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Now, we discuss about electrolytic aluminum smelting cell. What happened here? We have a bath which is nothing but molten cryolite bath which is maintained at 950 to 1000 degree centigrades and then within this bath carbon electrodes are being introduced and then there is a press head.

So, continuously these electrodes are formed from coke and pitch and continuously being supplied here and then provided here. So, this electrode is inserted into this cryolite bath which is at high temperature and to this bath from the top continuously you are supplying you know alumina  $\text{Al}_2\text{O}_3$ .  $\text{Al}_2\text{O}_3$  you are supplying. So, that you always have at least 3 to 5 percent of  $\text{Al}_2\text{O}_3$  present in the cell, right.

So, in this bath when this  $\text{Al}_2\text{O}_3$  is introduced at this electrode surface what happens the reaction takes place that Al is produced as well as CO is also produced. This CO may also react with the electrodes. So, that to give  $\text{CO}_2$  as well so, this CO,  $\text{CO}_2$  are released from the top from here like this.

Whereas, the liquid aluminum whatever formed at the bottom that is continuously taken from the bottom here we have removable clay plug as well. For the removal of the any of the waste material or for the collection of the product as well it can be utilized either way it can be utilized, ok.

This is a brief about an electrolytic aluminum smelting cell. Briefly, what you understand here is that you have a molten bath of cryolite in which carbon electrodes are introduced continuously. This molten cryolite is at a high temperature, like 950 to 1000 degrees Celsius. To this hot molten bath,  $\text{Al}_2\text{O}_3$  is being supplied.

So, when this  $\text{Al}_2\text{O}_3$  is coming and interacting with this bath at the electrode surface, what happens is the reduction reaction takes place to get aluminum plus CO. That CO may also react with the electrodes to produce  $\text{CO}_2$ . So, the CO,  $\text{CO}_2$  taken from the top, whereas, the aluminum liquid is collected from the bottom, right. So, as the electrodes are being consumed for this reaction, they are continuously formed and then you know they are provided, supplied continuously into the cryolite bath, ok.

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**Process description:**

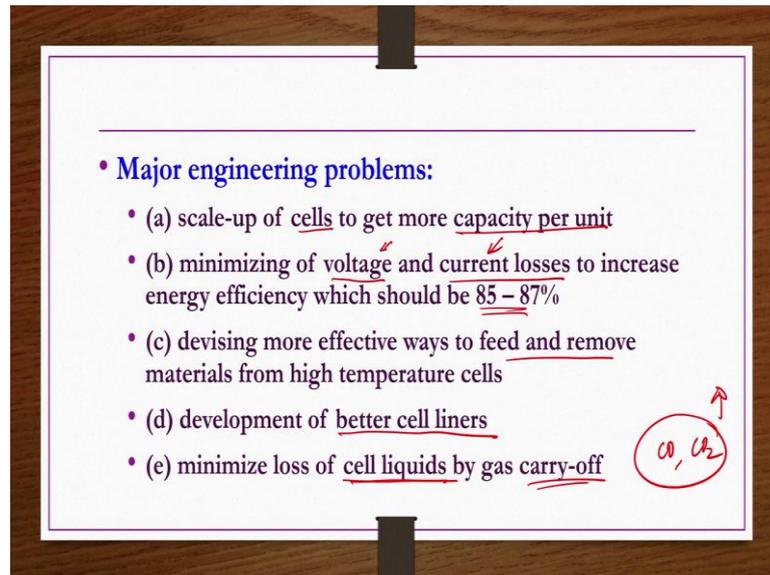
- Molten cryolite bath is maintained at 950 – 1000°C
- To this bath, alumina is dumped periodically into each cell to keep a 3 – 5%  $\text{Al}_2\text{O}_3$  concentration
- Reduction takes place at the graphite anodes
- These are either fed continuously or replaced batch-wise as they erode
- Aluminum drops to the bottom of the cell and is periodically tapped off
- Purity of this aluminum is not greater than 99.7% which is poor quality for electric conductor usage

So, description part of this process if you see molten cryolite bath is maintained at 950 to 1000 degree Celsius to this bath alumina is dumped periodically into each cell to keep 3 to 5 percent of alumina concentration within the bath continuously, ok. Reduction takes place at the graphite anodes. These are either fed continuously or replaced batchwise as they erode because the reactions are taking place at the graphite anodes, ok.

Aluminum drops to the bottom of the cell and this periodically tapped off. Purity of this alumina however, is not greater than 99.7 percent so, which is not good enough quality if you wanted to use this aluminum for electric conductor usage. So, then it has to be



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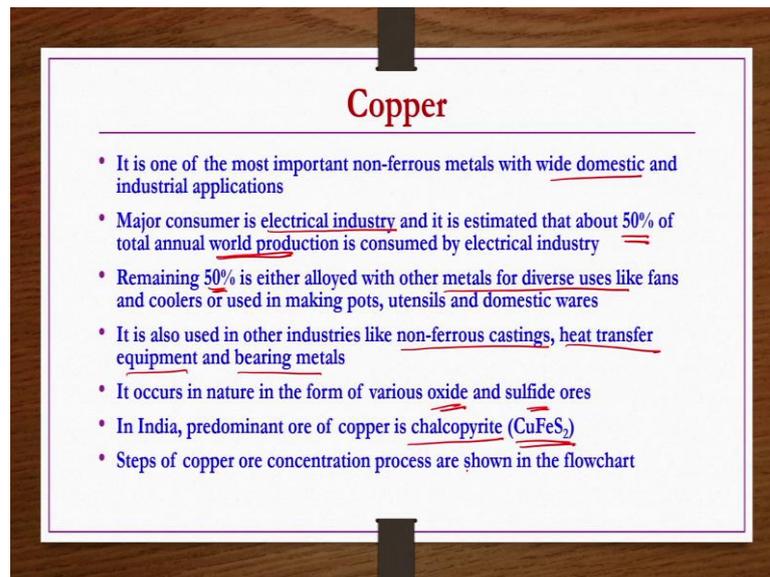
Major engineering problems of this process if you see scale up of cells to get more capacity per unit is one important issue. Then minimizing of voltage and then current losses to increase energy efficiency is another issue.

So, because minimum energy efficiency should be 85 to 87 percent that efficiency may be improved if you reduce the loss of voltage and current, ok. Devising more effective ways to feed and remove materials from high temperature cells is another issue and then development of better cell liners as well.

Only graphite liners we have seen. So, better cell liners could be more beneficial and then minimizing loss of cell liquids by gas carry off whatever this CO, CO<sub>2</sub> gases are forming and then they are taken out. So, when these gases are going out. So, then some of the cell liquids is also going out that is cryolite molten cryolite is also going out.

So, how to reduce such losses that is another engineering issue one should think about. So, that is about the alumina purification followed by aluminum production by electrolytic reduction of alumina, right. Now, we discuss about copper.

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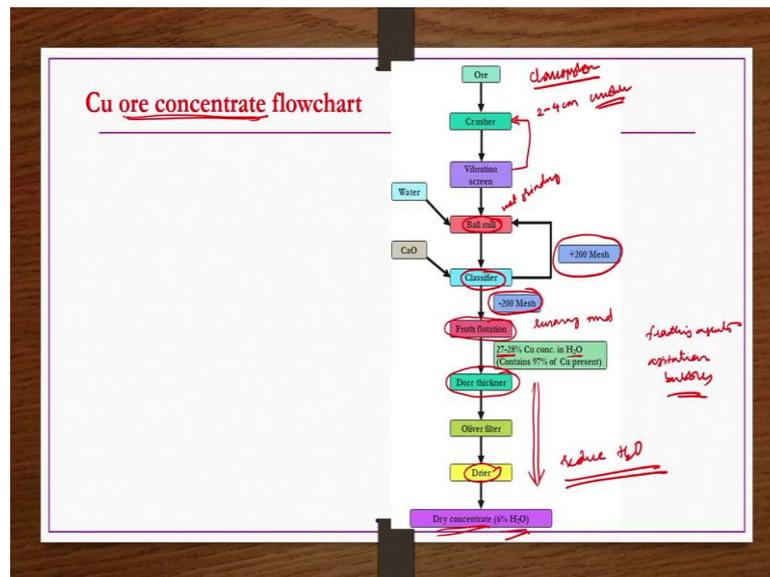


It is one of the most important nonferrous metals with wide domestic and industrial applications as well. Major consumer is electrical industry and it is estimated that about 50 percent of total annual world production not only Indian world production of copper whatever is there 50 percent of that is used by the electrical industry. That much copper is required for the electrical industry because of its electrical conductance.

Remaining 50 percent is either alloyed with other metals for diverse uses like making of fans and coolers or used in making pots, utensils and domestic wares etcetera. It is also used in other industries like nonferrous coatings, heat transfer equipment and then bearing metals etcetera for those purposes also it is used.

It occurs in nature in the form of various oxide and sulfide ores. In India predominant ore of copper is chalcopyrite which is nothing but  $\text{CuFeS}_2$ . Chalcopyrite is the major or predominant ore of copper in India. Steps of copper ore concentration process are shown in the flow chart here.

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Whatever chalcopyrite ore is there that you take it and then crush it. Crush it to few sizes like 2 to 4 centimeters in crushers, gyratory crushers, jaw crushers etcetera are used, but such sizes are not good enough. So, but what you do then you do the vibration screen whatever the material having the bigger than the 2 to 4 centimeter size they will be fed back to the crushers whereas, the materials having 2 to 4 centimeters are smaller than that one they will be taken to a ball mill where wet grinding takes place using water.

So, here further size reduction takes place because the purpose is to reduce material to minus 200 mesh. So, after the ball mill or the you know grinding in ball mill by wet grinding method whatever the material is there that would be pass it through a classifier. Classifier is nothing but the size separation equipment, right.

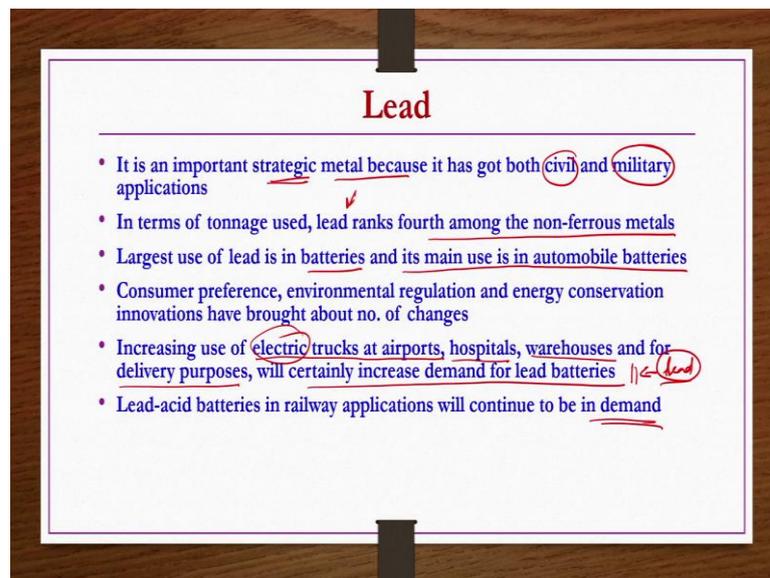
So, here the size of material which are having the size minus 200 mesh are smaller they will be taken to the froth flotation cell for the further processing whereas, the material which are having size more than plus 200 mesh size they will be sent back to the ball mill for further wet grinding. So, that required size reduction may take place ok.

So, in the froth flotation required purification of this ore takes place by removing mud etcetera. In the froth flotation what you have? You have the steps like you know frothing agents are required then agitation is required to form the bubbles. So, in the froth flotation whatever the bubbles form.

So, they will be carrying the lighter minerals of copper whereas, the heavier mud etcetera gangue etcetera would be at the bottom of the flotation cell they will be discarded as waste whereas, the concentrate which is having 27 to 28 percent copper concentrate in H<sub>2</sub>O is taken for the further process by Dorr thickener followed by Oliver filter and drier to increase its dry concentrate to less than 6 percent H<sub>2</sub>O .

So, all these processes subsequent processes is to reduce H<sub>2</sub>O because whatever that purified ore that is coming from froth flotation is having lot of water. So, that water has to be removed by these steps and so, that you can have a dry concentrate ore which is having only 6 percent of water or less, ok. So, this is the sequence of steps that are occurring in copper ore concentrate process it is a ore concentration process only.

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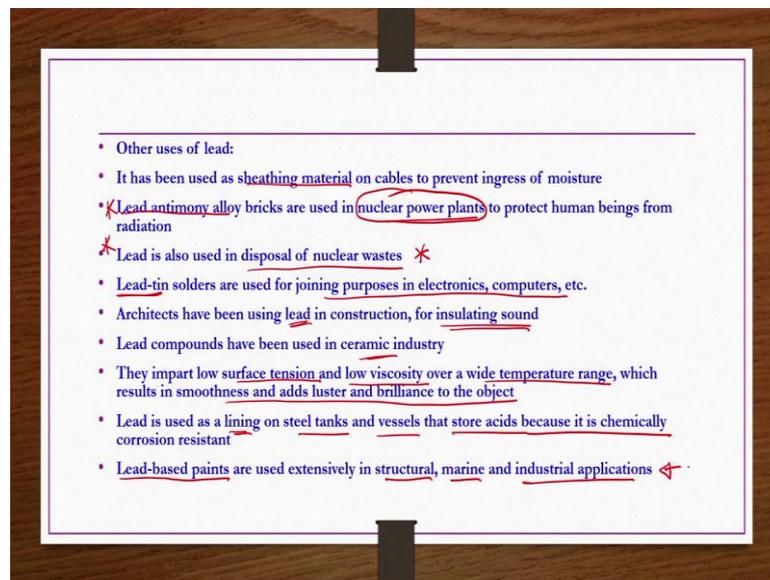
Now, we talk about another nonferrous metal which is lead. Lead is an important strategic metal because it has got both civil as well as the military applications. So, that is the reason strategically it is produced and then utilized. In terms of tonnage used lead ranks fourth amongst the nonferrous metals, fourth largest utilized nonferrous metal is nothing but the lead. Largest use of lead is in batteries and its main use in automobile industries.

We see that you know most of the lead batteries or lead acid batteries are used for the you know for different purposes. Consumer preference environmental regulation and energy conservation innovations have brought about a lot of number of changes in the

process. Increasing use of electric trucks at airports, hospitals, warehouses and for delivery purposes will certainly increase demand for lead batteries.

So, lead production is going to shoot up anyway because its applications are used everywhere nowadays, we are talking about electric vehicles, ok. Lead acid batteries in railway applications will continue to be in demand because railway utilization is continuously increasing year by year for different purposes. Not only for the passengers purpose, but also for the goods transport purpose as well.

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If you see other uses of lead, it is having several applications it not only as a battery. So, what are the other applications? If you see it has been used as sheathing material on cables to prevent ingress of moisture. Lead antimony alloy bricks are used in nuclear power plants to protect human beings from a radiation. So, in the nuclear plants it is one of the important thing actually.

Not only for this purpose for this lead antimony alloy bricks formation purpose, but also for the discharge of you know nuclear waste whatever the nuclear waste discharge purpose also lead is used extensively, ok.

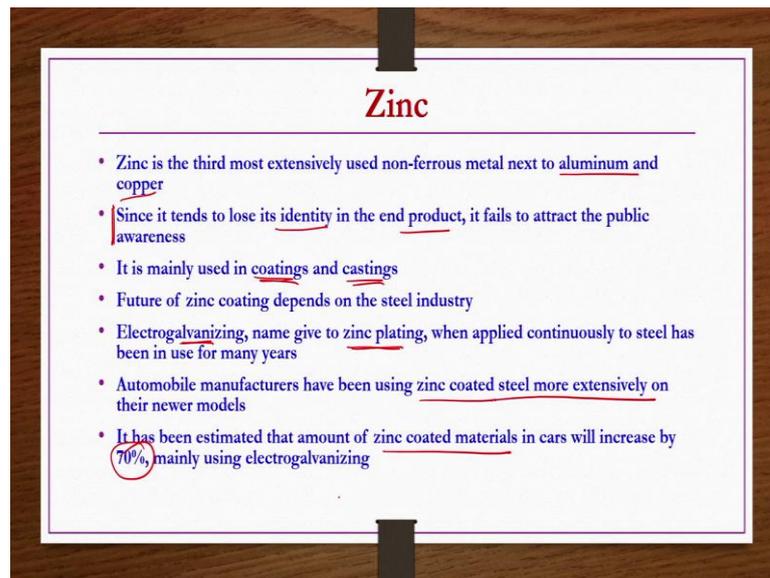
Lead is also used in disposal of nuclear waste as well. So, it is a very important application that it is having in nuclear plants. Then another kind of alloy that is lead tin

alloy it is used for joining purposes in electronics, computers etcetera. Soldering purpose, it is used in these equipments.

Architects have been using lead in construction why using lead in construction because it provides sound insulation for that purpose it is used. Then lead compounds have been used in ceramic industries also we have seen. They impart low surface tension and low viscosity over wide temperature range, which results in smoothness and adds luster and brilliance to the object.

Lead is used as a lining on steel tanks vessels that store acids because it is chemically corrosion resistant. Finally, lead based paints are used extensively in structural, marine and industrial applications we have already seen some of them in paints and varnishes industries when we are talking about, right.

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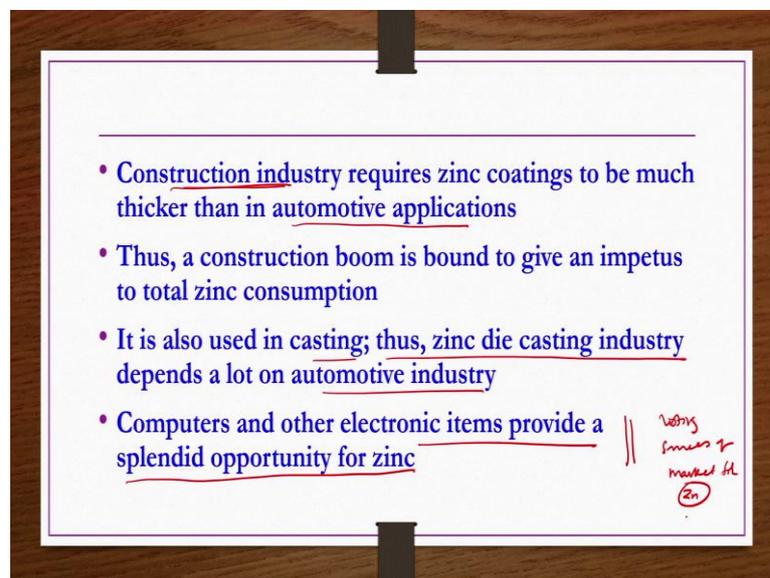
Finally, we talk about a another nonferrous metal that is zinc. Zinc is the third most extensively used nonferrous metal next to aluminum and copper. Aluminum and copper are the top utilized based on the tonnage utilization view point after that zinc and then lead are the ones you know mostly used.

Since it tends to lose its identity in the end product it fails to attract the public awareness that is a major problem with this one. It has several applications, but what happens it lose its identity when it is used for certain kind of end products.

Some of them will see now it is mainly used in coatings and castings. While doing the coatings and castings we do not realize that zinc has been utilized. We realize about the other major coating materials. Future of zinc coating depends on the steel industry. Electro galvanizing which is nothing but zinc plating this when you apply it continuously to steel has been in use for many years.

Automobile manufacturers have been using zinc coated steel more extensively on their newer models as well. It has been estimated that amount of zinc coated materials in cars will increase by 70 percent mainly because of using electro galvanizing.

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Further construction industry requires zinc coatings to be much thicker than in automobile application. So, then obviously, when there is a boom in construction industry then obviously, there would be demand for the zinc. So, zinc production is also going to be having a good market. Thus, construction boom is bound to give an impetus to total zinc consumption.

It is also used in casting. Thus, zinc die casting industry depends a lot on automotive industries. Finally, computers and other electronic items provide a splendid opportunity for zinc. So, we are listing the sources of market for zinc which may be already there or may be chances of increased market for zinc that is what we listed now here.

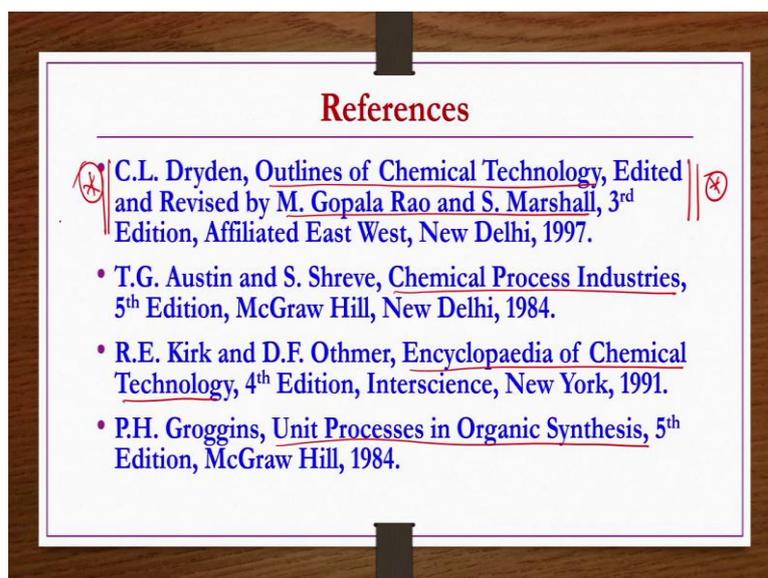


many what are the ones you know  $H_2SO_4$  you are getting then you are getting Zn and then you are getting cadmium also, right.

So, this  $H_2SO_4$  if you react with the phosphate rock then you get the fertilizers also. So, any plant if you have. So, you try to get as many products as possible then only any plant can be economically growing faster compared to the other plants. If you depend only on one product and then discard the other ones or the other byproducts the product the plant is not going to be economically well established, ok.

So, this is all about metallurgical industries this much information is sufficient from UG chemical engineering graduate point of view the references for today's lecture are provided here.

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Outlines of Chemical Technology by Dryden edited and revised by Gopal Rao and Marshall. Then Chemical Process Industries by Austin and Shreve 5th edition and Encyclopedia of Chemical Technology by Kirk and Othmer, finally, Unit Processes In Organic Synthesis by Groggins. However, the entire lecture notes that presented in today's lecture is prepared from this reference book.

Thank you.