Industrial Inorganic Chemistry
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Lecture – 28
Ion Conduction Membrane in Electrolysis

Hello and welcome back to this class of chlor-alkali electrolysis what we are discussing. So, in that particular class already we have discussed two different types of electrolytic process.

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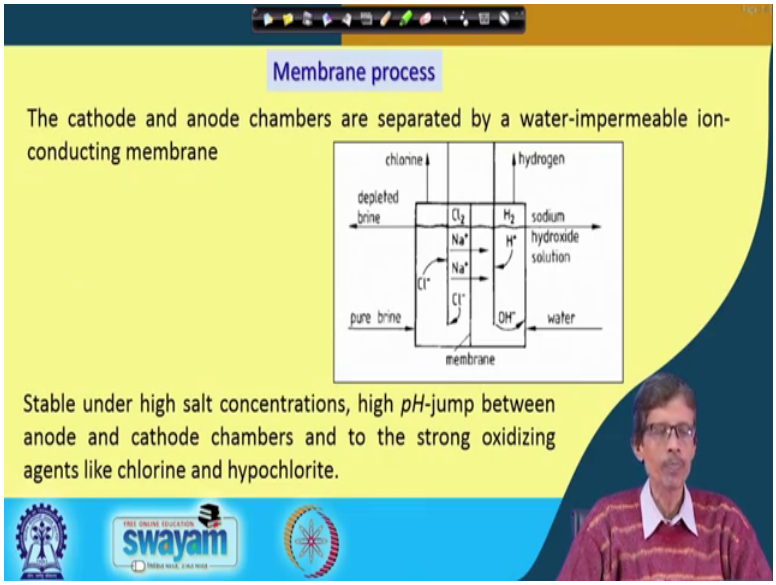

So, third type we will discuss now which is the introduction of the membrane. So, introduction of the membrane within the electrolytic chamber will give you the third category of the corresponding electrolysis process for the chlor-alkali electrolysis producing sodium hydroxide as a solution material which we get in the solution and two gaseous products chlorine and the hydrogen.

So, diaphragm process what we have seen the diaphragm technique what we have discussed and that particular diaphragm technique is separating the anodes and cathodes now the process what we are now seeing is instead of your diaphragm now we introduce a membrane. So, membrane is basically another finer material another material which can have some obstruction for permit some of this material because we all know that membranes can be semi permeable we considered is as the semipermeable membrane;

so, which can permeate or can allowed to go some of this species through that particular membrane and others will be retained.

So, in this particular process that membrane process you should know very clearly the typical process by name the definition may be some of this process are outdated we still may not continue because some of them are not so useful and is energy extensive also like your first process that mercury process that mercury electrode process. So, day by day we can have some improvement, newer techniques will come, but the original process what is involved for the electrolysis is still remains only thing the challenge is always there for the industrial sector is that how to produce the material at a low cost.

So, the old materials and old processes are outdated; we should go for the new techniques, but the material still available because we are talking in terms of typical inorganic materials as your bulk material or the commodity material that will not change; only thing that how easily and how quickly we can get the material at a cheaper way.

So, you have now two chambers. So, now, we are talking like that of your cathode and anode. So, you now have the cathode and the anode chambers which will be separated by a water permeable ion conducting membrane. So, you should be knowing now that what are the typical definition of these; that means, as I told you that it is semi permeable one. So, what is that semi permeability of that particular material? Earlier in case of asbestos we have also seen that it is only allowing the liquid to pass, but it is not allowing the gaseous material to pass that is why two different chamber for the two gaseous material what we can have.

So, is water-impermeable one, so ion-conducting membrane. So, if we now allow the membrane attach to it which will not allow water to pass; that means, whatever hydroxide ions if you are able to produce will not be allowed to mix with the sodium and then how you get the sodium hydroxide. So, that will see now that you have the pure brine water and you get this as the corresponding one; that means, you have the membrane in between. So, you have the cathode and the anode sides there and this cathode and anodes we can get. Therefore, for the introduction of the pure brine at the bottom and as the electrolysis process is going on your amount of sodium chloride is going less and less and at the end basically this particular one is taken out.

So, the solution which is less concentrated is sodium chloride is your depleted brine; that means, less concentrating we are less concentrating our material in terms of your sodium chloride and by that time through the side of these two electrodes you get chlorine and hydrogen and also through the production of this hydroxide ion with this water you get with this particular chamber; that means, you are the chamber on the right hand side will be responsible for producing your sodium hydroxide unlike the two other techniques.

So, if you just simply study these three techniques you should be able to compare these three techniques and where you are sodium hydroxide is being formed. And, if you the flowchart is given to you should be able to recognize or identify that this flowchart for the cell is basically not even 3-dimensional drawing is a very simplest one is a block diagram we call out the flowchart we call. So, the flowchart basically will tell you which particular process we are talking about because sometimes if we not give this membrane to you that is membrane is not given to you because otherwise it will be quite obvious that will be able to recognize it as this is meant for the corresponding membrane process.

But, the orientation of this thing and the production of the sodium hydroxide from one particular chamber towards the right hand side will immediately tell you that this is a membrane process through which on the right hand side on the top you get the production of your hydrogen gas and on the side will be getting your sodium hydroxide solution. And, which is less concentrated with respect to your sodium hydroxide sodium chloride also along with your sodium hydroxide because this sodium will go and pass through this particular solution and this water is not allowed. So, only sodium ion; that is why it is ion conducting membrane or is which is water impermeable. So, ions are moving. So, sodium ions will move and reach over there I will go for it is reduction.

So, this anode material will be there for responsible for the reduction of your sodium also and that sodium will react with this if it is not reacting directly with your hydroxide ion. So, this sodium can go and react with hydroxide and producing a sodium hydroxide or the potential what you can set is not allow you to reduce this particular electrode to get you sodium as your sodium reduced form as sodium zero.

So, what you get that this particular membrane and your membrane the stability of the membrane is also important because you are handling a very high sodium chloride concentrated solution. So, concentration of sodium chloride is pretty high. So, the

materials would be stable under high concentrations. So, your membrane material it should be a polymeric one. So, polymeric material which you will not be able to attack it with a high salt concentration and there will be a high pH-jump between anode and cathode chamber because your producing more number of hydroxide ions because hydroxide ions are getting accumulated over there and hydrogen ions are getting reduced to produce your hydrogen gas.

So, you have a strongly alkaline solution on the right hand side or the right hand chamber so, your material for the preparation of the membrane should be such that it should with stand a very high pH; that means, the alkaline pH and there is a pH-jump between anode and cathode chamber. So, the membrane what is there? So, on one side you have a pH of different type compared to the other side where pH is going up for the production of sodium hydroxide and strong oxidizing agents like chlorine and hypochlorite because the chlorine is also producing. So, is a very drastic condition. So, industrially all these things always be try to remember that when a industry is formed there can be if certain amount of negligence or neglect is there it can have a typical disaster.

So, industrial accidents are quite obvious that is the reason because the thing what you are handling is highly in all respect that is highly concentrated highly in alkaline medium and your pH difference for these two chambers are very high sometimes it is a doing that high reaction temperature also. So, you should always very much careful because the huge amount what is being used. So, here you see not only the high salt concentration of sodium chloride you have a pH-jump from one chamber to the other. So, you are membrane should with stand these two as well as it should not be oxidized by the chlorine what is being produced and the hypochlorite which we all know is bleaching agent and the bleaching function is only originating from its high reactivity.

So, chlorine is the highly oxidizing agent hypochlorite is also highly reacting agent or highly oxidizing agent and is also a bleaching agent. So, these two are highly reactive. So, in alkaline medium the available chlorine and little bit of hypochlorite as we have already discussed that some amount of hypochlorite in presence of sodium hydroxide will be formed through the reaction of chlorine gas and sodium hydroxide.

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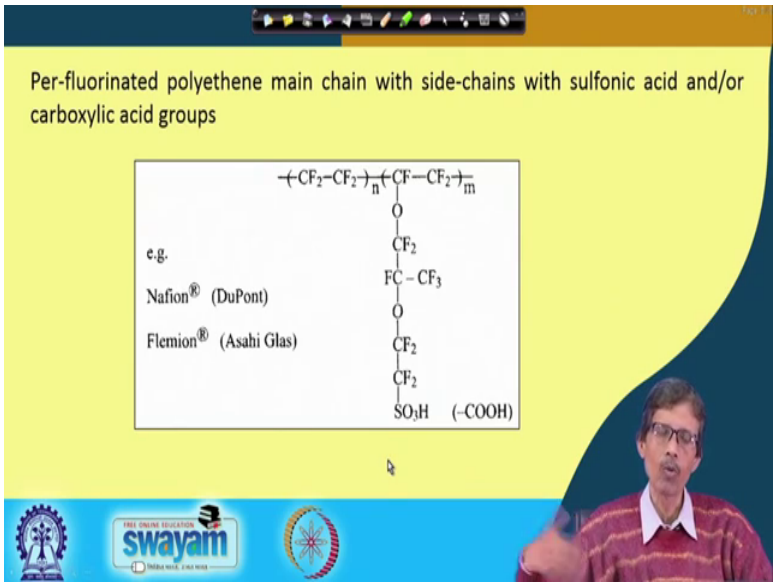

So, all these things should give us a useful membrane which can be utilized for this purpose. So, what is that? So, material should be per-fluorinated polyethene main chain. So, polyethene main chain we know that is the polyethylene chain we know like that of your Teflon material already we have discussed earlier while we are considering the flourine and is usefulness for making new material or useful material for industrial point of view.

So, per-fluorinated; that means, all the CH bonds will be replaced by CF bonds within the main chain and only thing you have the side chains with sulfonic acids and or carboxylic acid because you have to make it ionic; that means, it is ion selective material or ion selective membrane because it can take care of the sodium ions. So, if you use sulfonic acid which is negatively charged as the anion sulfonic acid and ion SO 3 minus or the carboxylic acid end the CO 2 minus end. So, that can take care of large amount of sodium ions in it. So, that is why it would be a ion selective membrane. As we all know that, there are some electrodes which you considered as the ion selective electrode.

Similarly, this particular case these are ion selective membrane. So, these two are commercially available thing one is the Nafion another is the Flemion. So, the name is also is a commercial name because is typically a trade secret, it is patent protected also. Sometime the material is introduced people a, but do not know what material is being used. Even the other company or other industry which is a competitor of the first one will

not go for knowing this particular material. Since these are pretty old one and is a basically now it is a textbook knowledge and is a knowledge to every students that what DuPont was using as a Nafion because in the trade name of Nafion. This material is available; some company also the chemical company the polymer company they are making this Nafion to the people for other purpose not for this purpose only.

But, sometimes the need basically the need of using this particular membrane material you can have a good research and development activity for that particular purpose for making or developing a new material for this particular purpose. So, that way the company is your DuPont. So, DuPont was responsible for making this Nafion and it is patent protected and all you know that once a material is discovered or the research item what is being published not in the regular academic journal, but you can publish it in the patent or it is a patent protected item and that patent protected item can have some lifespan only. So, it can have a 10 years or 20 years of patent protection, after that it can come to a general knowledge, it can be your textbook knowledge or a people can know by that time what people are using.

So, by two names basically because simultaneously two company the two competitors can do together the development of this particular material. So, other one is Flemion the name is different. But, the material is same, but the second one if we consider that first people have identified as the sulfonic acid functionality, the second people can use it as a carboxylate functionality; only little bit different in their corresponding activity or the corresponding effectiveness for the material for that particular purpose. So, Asahi Glas – G l a s s this is s s, a glass Asahi Glas and the DuPont they are making these having a typical backbone.

So, you have per-fluorinated polyethylene backbone like that of your teflon. So, you have and you can have a side arm which is ending with a sulfonic acid or the carboxylic acid side chain. But, you can see that there are some ethyl oxygens also; so, ether oxygen placement within the backbone also giving you some material characteristics or some flexibility in it. So, in terms of your understanding that how you define or how you tell about people about this membrane is that it is a per-fluorinated material of different length is n value and n value in the polymer chain is also known and on the n side the m, n you have one particular carbon you have the arm over there. So, how many n and how many m and how these two things are repeated along the chain is also known you have

the ether backbone over there and at the end basically you have the corresponding arm sensitive groups that means your carboxylate and the sulfonic acid groups.

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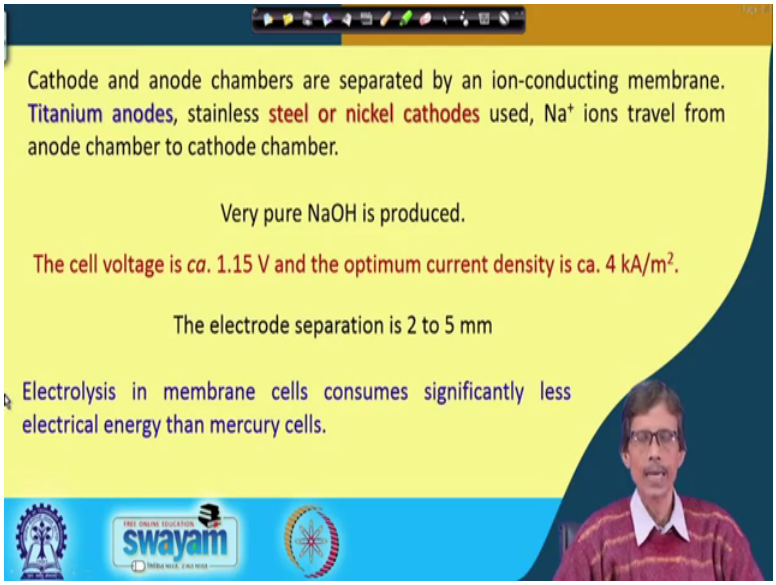

And, the chambers what we are using the cathode and anode chambers are separated by this particular membrane and you have the anodes which are titanium anodes or cathodes are still as well as the nickel cathodes. So, stainless steel or the nickel cathodes are used and as a result of using this membrane sodium ions travel from anode chamber to the cathode chamber. So, that allowance is given that is why we are able to get sodium hydroxide products and form a particular chamber and is being accumulated and the advantage of this particular technique is that the purity of your sodium hydroxide produced in this fashion is increasing. So, very high grade of sodium hydroxide is being produced; we can consider it that if you exceed some level you can consider it as the corresponding analytical reagent or a guaranteed reagent for sodium hydroxide.

And, the recommended cell voltage which can give you very useful production of this material is about only 1.15 volt not much and the optimum current density is about 4 kilo ampere per meter. So, the current density is also very important to know that how much current is being passed at that particular voltage which is pretty constant. So, is a constant voltage electrolysis technique and the current density is also should be known and the electrode separation is not much very fine the separation is only 2 to 5 millimeter

apart you can put the electrodes together, only thing that you can have the membrane barrier. So, this barrier is important.

So, electrolysis in membrane cell consumes significantly less electrical energy than mercury cell. So, that is the major advantage what we are moving one after another on elaborately we are discussing three different techniques and this particular technique has the great advantage because the cost of production should be less if you are using less amount of energy as your electrical energy for this particular purpose compared to the first technique.

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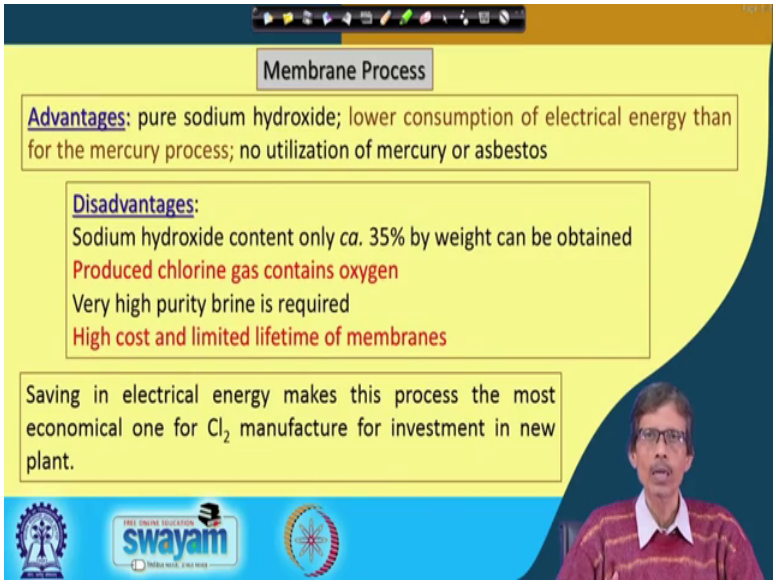

So, this particular membrane process has some advantages. So, the last technique we are not considering all comparison; that means, the first with second, second with third and third with first that is not the thing; only thing that what is the most useful one which can be utilize for different purpose because that brings you the understanding of the introduction of the membrane because the membrane we use so many places because the membrane is also nowadays a very good area of understanding, good area of knowledge and good area of research and development when we talk about the corresponding osmosis process a reverse osmosis process there we also use some amount of membrane in a high pressure we go for the separation of the unwanted ions from our drinking water.

So, you have the advantage of the production some of these advantages definitely all processes may not have only the advantages you can have also certain types of

disadvantages for this particular process. So, what you get the purity of the sodium hydroxide is very high. So, you get pure sodium hydroxide and what do you get as already told you that is the lower consumption of electrical energy than the first process and no utilization of mercury or asbestos which are environmentally harmful, because nowadays some of these technique basically are banned. So, industry people are facing lots of trouble to get the environmental clearance.

So, if it is not helping or if it is destroying our environment then that particular procedure whatever good it is will not be allowed to run for the industrial sector. So, industrial sector the first thing is that they should have the useful clearance from the environment department basically. So, environment protection agencies are there. So, these two things the mercury is a very bad material for contaminating your environment. Similarly asbestos is also a very bad material because it goes to our lung and it can considered because is a basically silicon material. So, silicosis is the disease which the people working on making this asbestos.

So, we should reduce the use of asbestos day by day because it is earlier it was a typical building material for making our roof asbestos sheets basically like our steel sheets or the tin sheets we were using the asbestos sheet because at that time probably our country was not so rich we cannot afford. Because we only we can afford the asbestos only that time. So, making of all these asbestos, including the use of these asbestos as a material for electrolysis has been totally stopped.

So, we can have only the development on this membrane process and if we just simply follow the history of this particular development that how it has been developed you will be tempted to develop further because you have to go ahead with the further development of that particular process from this membrane technique. So, if you have now in your hand the membrane technique how you can go further to improve this particular technique in terms of the membrane material, in terms of electricity consumption, in terms of designing the electrolysis chamber and all these.

So, the disadvantages: so, definitely the new technique will improve is improved technique and which will also eliminate the disadvantages what we can follow for this particular membrane process. So, one of the major disadvantage is that only up to 35 percent by weight content of sodium hydroxide will be able to produce by this particular

technique. So, you have to go for concentrating more and more amount of the volume bulk what is being produced from the electrolysis cell, but this not a very bad amount, but is not very high; that means, it is not above 50 percent as yield of a particular material because the industry always looking for certain amount of production because you have the production cost and the production technique and manpower all these things related. So, people are happy in industrial sector, but if you are able to produce something above 90 percent, so, yield if the yield is 90 percent they are very happy.

Then the produced chlorine gas because some amount of this production will also contain the oxygen as we all know that the electrolysis of the water because we are adding water to the system. So, electrolysis of water can give rise to the production of hydrogen as well as oxygen. So, we cannot eliminate until and unless you change or to design the new electrotype, new electrode material you cannot avoid the contamination of the chlorine gas by the corresponding oxygen available through that particular oxidation of the water molecules.

And, very high purity of brine is required because the supply of the raw material if you spend more money in improving the purity of the brine, it will not be that much cost effective for the industry. So, always you require a very high purity brine. So, the other two techniques what we have discussed those two techniques can handle the low grade brine material. So, that is one of the obstacle for this particular technique then high cost and limited lifetime of the membrane. So, basically is a very cost is not a cost effective one. So, is a costly affair in terms of the different types of membrane until and unless the polymer industry can help you in making these two membrane at a very cheaper way or at a very cheaper price.

So, the cost of the memory is also a disadvantage for this particular process and as a result what we can do we can do for this particular one that you can save the electrical energy still people make it for these the most economical one for the chlorine manufacturing process is a most economical one and for the investment in new plant. So, if you save the money you can go for the investing a new plant or you can utilize the produced chlorine because we are getting chlorine out of this. So, you can utilize that chlorine basically for making new types of material which are value added.

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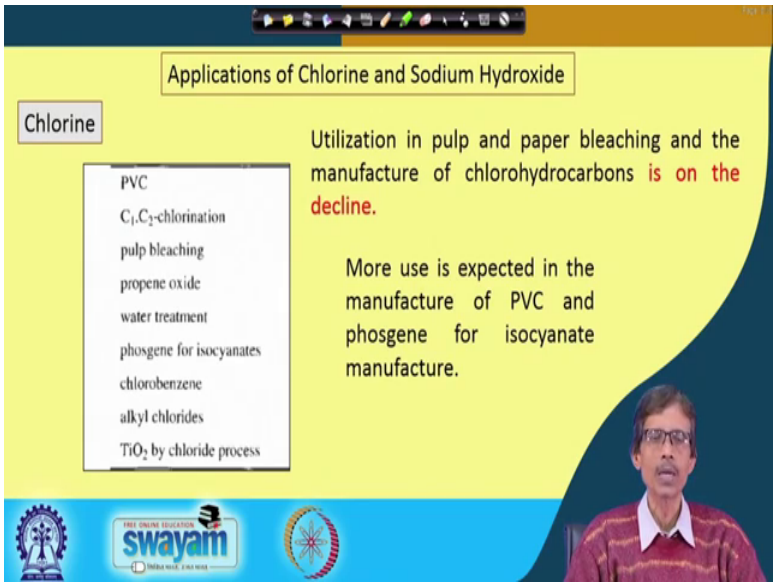

So, application: so, these two components also we will see the application wise this application of chlorine as well as application of sodium hydroxide because much lesser amount of hydrogen as gas is produced through this particular methodologies. So, we will not discuss for that only because hydrogen usefulness is nowadays we know, but you have to produce the huge amount of hydrogen out of water or out of any other technique so that hydrogen can be utilized for the as a useful fuel also.

So, application of chlorine will tell that the first one the chlorine. So, chlorine as we know is a very good oxidizing agent and it has a corresponding oxidation potential also very high which is 1.35 volt. So, if we can bleach some paper and the pulp material, the bulk material for the production of the pulp and the paper bleaching cases the pulp for making the paper it is very much useful because it can bleach for the whitening basically little bit of whitening of those material the starting material for making paper and it is useful for the manufacture of the corresponding chlorohydrocarbons on the decline.

Once we write because long back we were utilizing this a huge amount of this is being used for bleaching purpose as well as making the chlorohydrocarbons as well as also the chlorofluorocarbons the chloroform, the dichloromethane, the carbon tetrachloride these are all different types of chlorine bearing solvents and the reagents and organic compounds, but the demand is declining because again these are harmful for the environment. So, mostly while we can use selectively we can choose all this things

where we can utilize because the use of those materials and the demand in the market is also very important.

So, making of your PVC is there. So, polyvinyl chloride preparation say again is a chlorine base material we have used then CC chlorination that mean the chlorination of the different organic compounds whether you are using a pharmaceutical compound or a medicinal compound still we are using pulp bleaching. But, if you can go for a the corresponding consideration that is a at a low concentration then making of the propene oxide, water treatment, phosgene for isocyanate preparation. So, this isocyanates are having a huge demand in industry; then making of chlorobenzene, alkyl chlorides and titanium dioxide by chloride processes.

Because, there are some processes which are involving the use of chlorides. So, those chlorides can come from your typical Cl 2 gas only. So, more use is expected in the manufacture of the first type; that means, the matching and the manufacturing of the PVC and the other one that mean the phosgene; that means, the phosgene for isocyanate manufacturing because we know that the Bhopal gas disaster what has happened due to the formation or the storage basically methyl isocyanate. So, for the agriculture industry for making the insecticides and the pesticides all these things this is a very good starting material that is if you are not going for making the MIC, the methyl isocyanate, but some other isocyanides it is going through the phosgene which is COCl 2 the phosgene preparation is also dependent on the industry like this, that means the chlorine industry.

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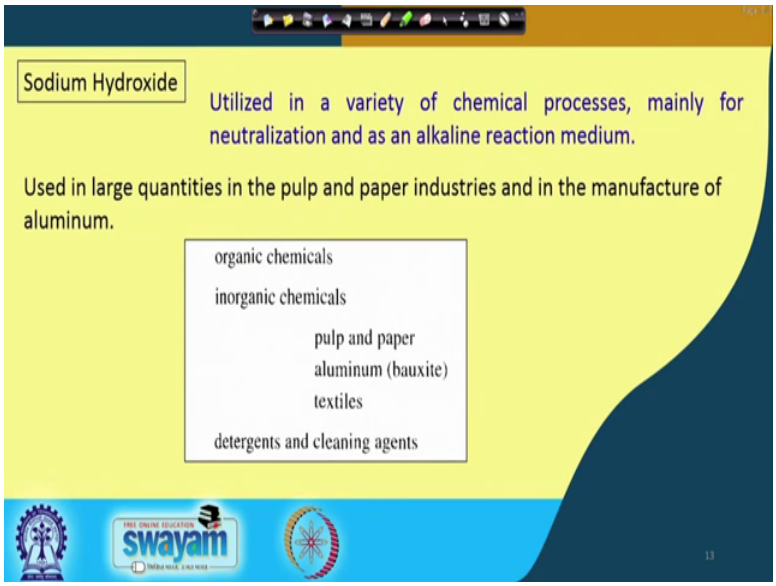

Then, the industry which we if there is a looking for your sodium hydroxide. So, sodium hydroxide is being used starting from your typical academic lab or a teaching lab to research and development area everywhere and lastly to. So, many industry sodium hydroxide is required because you in a cheaper way like sodium chloride as a table salt the sodium hydroxide you can use in a cheaper way to maintain the corresponding alkaline medium or the alkalinity of the corresponding process.

So, different chemical processes are benefited by the use of this particular sodium hydroxide what is being produced over there and mainly it is utilized for the neutralization or as an alkaline reaction medium for different types of reactions and in large quantities still it is used in the pulp and the paper industries and in the manufacture of aluminum as we have seen earlier that we can use this in the manufacturing of aluminum where we use that particular one that is for the corresponding formation of aluminum hydroxide formation from your bauxite or any scrap aluminum. So, formation of this aluminum hydroxide because that can be converted to aluminum trifluorite and then to cryolite, we have already seen these processes.

So, the sodium hydroxide requirement or the demand is very high the over there for your production of this aluminum through the electrolysis of the cryolites. So, these sodium hydroxide will be utilized for making large number of organic chemicals also because the different types of reactions in the alkaline medium at a very high pH value you

require the sodium hydroxide as the most favored and the cheapest medium for this reaction compared to your other hydroxide medium like potassium hydroxide or any organic bases liked tri ethyl ammonium hydroxide or tetra methyl ammonium hydroxide. So, it is a most cheapest alkaline organic medium which can be provided to you for the reactions.

Then, large number of inorganic chemicals whether you are may getting some sodium based compound or the hydroxide based compound you require sodium hydroxide for the production of inorganic chemicals. Then as I told that pulp and paper industries, aluminum industry and the textile industries also useful for that and then finally, the detergents and the different cleaning agents are also utilized for these particular processes. That means, where we use sodium hydroxide for making detergents and the different types of cleaning agents. So, that is gives us a very good idea that how the chloro-alkali process can produce so many useful chemicals and which can further we utilized in different industrial sectors because this can be utilized in different areas, ok.

So, thank you very much.