Industrial Inorganic Chemistry
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Lecture – 37
Sodium and Its Compounds

Good evening everybody. So, we are still talking with the alkali metal ions, their production in this particular class. So, now today we will see, how the production of sodium industrially and its different compounds can affect the course of our study, where we can see basically how in the elemental form, we can get the sodium.

As we all know that when we are handling sodium in the laboratory purposes also, the sodium as small blocks of metals come under some inert solvent like kerosene. So, how we get that particular sodium if you have a huge source of sodium chloride from seawater or brine, so that we will see that.

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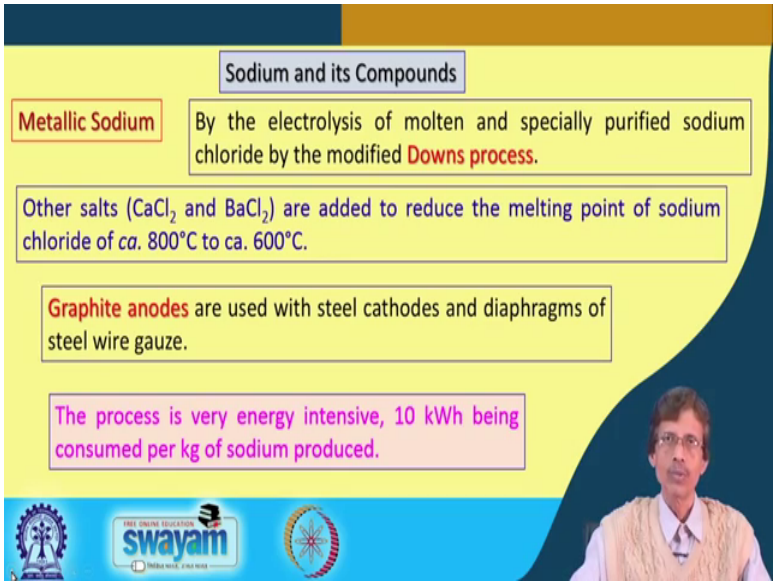

Starting from your sodium and its different compounds, though it seems very simple that how we get sodium, but thing is much more complicated. If I ask you that how you get sodium from sodium chloride, which is the typical natural source from our sea water or any lake water or any salty water or brines.

So, these will see and then some very important compound based on the sodium such as sodium borohydrate or any other compound, because most of these compounds we know the industry is flooded with large number of sodium salts including the pharmaceutical industry. Because, this particular sodium salt, if it is a typical organic compound like that of your sodium benzoate or any other sodium salt, we know that we are converting typically benzoic acid to sodium benzoate is in its salt form, so that particular salt will have a higher solubility in water.

So, it can go up to the level, where we can use it in the food industry. So, the food industry the addition of all the sodium salt can be the subject matter of this particular course if we think nicely, that how we can use sodium and its different useful compounds as industrially important.

So, the first thing what we can see now, that how metallic sodium we can get. So, how this particular thing can be useful, because we can have huge supply in the laboratory also. Starting from our school laboratory to college to university or any other laboratories, we can have a good source or good supply of metallic sodium for some useful analytical purposes or useful analysis.

So, this can be processed or this can be obtained by simple thing is that the electrolysis of molten and specially purified sodium chloride. Just now as I told you that you can have huge supply of sodium chloride from the seawater also. So, you get a huge amount of sodium chloride, but industrially you should know how that particular sodium chloride that means, N a plus C l minus present as the ionic salt can give you sodium as sodium 0 and the metallic form how you get that metallic form, whether you can take it as a molten one, molten sodium metal or in the liquid form or in the solid blocks.

So, one of these thing that means, that industrially important electrolysis process is the downs process and with time basically depending upon its feasibility of the particular process. We can go for the different types of modified downs process. The modified downs process will be useful for production of industrially important one of these alkali metals as your sodium.

What we do then that is not that typically you take sodium chloride and its electrolysis, but other salts such as your calcium chloride or barium chloride are added to some extent or some composition we know that how much of these two salts can be added. So, these

bivalent alkaline earth metal ions like calcium and barium salts, like calcium chloride, and barium chloride will be added to reduce simply the melting point of the molten sodium chloride, because the molting point of the molten sodium chloride otherwise very high.

To reduced it to some workable temperature range such as your 600 to 800 degree centigrade. Because, if you go for electrolysis at pretty much higher temperature such as 1000 or 1200 degree centigrade, your cost required to maintain that particular temperature would be very high. So, always the idea would be how much we can go down to a temperature, where we can get useful production of sodium through electrolysis that means, the reduction of N a plus to N a 0.

So, typically for this particular process as the temperature is one of the important factor to know to control. Similarly, what are the different cathodes and anodes, what we use for this particular electrolysis process? So, the carbon anode, simply we all know from our dry cell to any other cases that we use the carbon as useful anode may anode material. And the still not the carbon or any other thing that means, still now is your cathode and diaphragms of steel wire gauze.

So, wire gauze you have the steel cathode, and is a diaphragm we make where the wire gauze is there that we know that sometimes if we try to cover the entire cathode material, throughout the reactor or throughout the cell, like we do in our coulometric cell. When we do the coulometry, we have the typical wire gauze which is made of platinum sometime.

So, platinum wire gauze electrode is used, so is the net basically. So, wire gauze net is utilized for one of the electrode for that particular process. Similarly, the diaphragm of steel wire is utilized in a form of gauze to make it a cathode useful cathode. But, when we do, because as I told you just now that, you have to maintain a temperature of 600 to 800 degree centigrade. So, how you make it, through electrical heating only. So, the electricity consumption would be very high, that is why the process is also known as very energy intensive process.

So, the production of sodium industrially as sodium metal should be energy incentive intensive and we require 10 kilowatt hour is consumed for the production of 1 kilogram of sodium. So, the challenge for the people who are handling with these, who are

modifying the process, who are improving that particular industrial process is that how you can go down for a temperature, where we can reduce further from a temperature range, where just now we have seen, which is 600 to 800 degree centigrade, because as you are able to do it say 500 degree centigrade or 400 degree centigrade.

Some other complications can arise, but you can save the electricity, you can save the money in terms of its expenditure for the production, because always people can calculate it out that what we are doing for your industrial production, it should be always be cheaper. So, like that of your per kg production, how much electricity you need. And considering all other effects, considering all other expenditures, you should be able to tell how much is your total expenditure for the production of a kilogram of metallic sodium.

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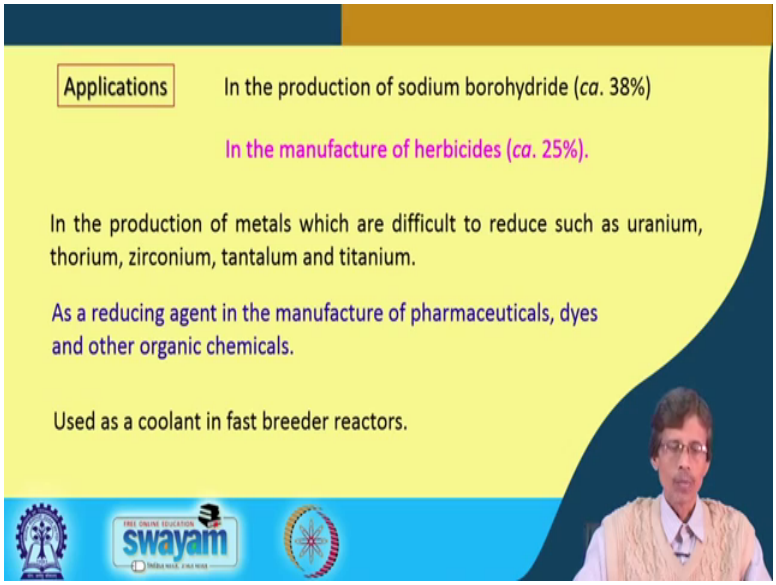

Then we find, what are those applications? Because, as we make the simple electrolysis process, so the basic principle we are looking at. We are not going for the typical electrolytic cell, its diagram and all these things this, because that will consume our entire class that will not do, but we will do some useful application, because the applications are very important.

Like that of your production of sodium borohydride. So, you see at that what is that borohydrate, so 38 percent of the produced sodium metal or the metallic sodium is consumed for the production of sodium borohydrate, where you have the sodium that sodium is coming N a plus is coming from N a 0 the metallic sodium. Then we have the

boron, whether we can use that boron from the diborane part or D H 3 or any other boron source or simple boric acid.

So, the boron source you must have, and then the hydrogen as its hydride, because it is a very useful compound. Sodium borohydride is very useful reducing agent for your organic chemistry, for any other thing, even for the production of metallic borides also. Then in the manufacture of different types of herbicides, because these herbicides are mostly the different types of sodium salts. And those sodium salts we consume a huge amount of this particular metallic sodium and the rough estimate of that consumption is 25 percent.

Then in the production of metals basically, some other production of metals in the domain of metallurgical engineering, where we know how we produce the metals, and some value added metals the alloys, from the available ores and minerals. Not all ores or not all minerals we can use for the production of that particular type of metal.

So, we will talk about something, because just now what we have seen that sodium chloride can be reduced electrochemically that means, if we use electrolysis for the production of metallic sodium, then if we just go for the production of uranium, thorium, zirconium, tantalum and titanium, these are some examples basically. And we should know immediately that what are the corresponding ores, we get that uranium to tantalum most of these we all know that naturally occurring all these ores are either sulphides, the carbonates, the hydroxides and oxides, so those basically should be reduced.

So, one of the process always you can answer that I can go for its electrochemical reduction or electrolysis, but that is the most difficult one and that is most also energy expensive also expensive expenditure for energy is also very high just now we have seen. So, what you can do, indirectly we can reduce some other metallic element as its reducing agent. So, sodium as in its metallic form can be used for the reduction of all these metals, because these metals are difficult to reduce through electrolysis also or through electro chemical reduction.

Then we can use these as the typical reducing agent that sodium we use sometimes sodium amalgam also. Sodium mercury, we write Na-Hg Na hyphen Hg, what is that is your sodium amalgam. Because, the mercury can dissolve some amount of sodium, and that will be very useful reducing agent as sodium amalgam.

So, like your sodium borohydrate to sodium amalgam, it can be your typical reducing agent in the manufacture of pharmaceuticals. Large number of pharmaceutical molecules, you can have that. One of the step is here your reducing step, where you can reduce either a c c double bond or (Refer Time: 12:04) nitrogen carbon nitrogen double bond or carbon oxygen double bond or some other functional groups, we have to reduce it to get the desired pharmaceutical agent or different pharmaceutical molecule.

Then we can go for making the dyes. Because, the dyes if you get like that, just now we told you the about the corresponding formation of sodium benzoate from benzoic acid. Similarly, the dyes are also sometimes available, whether it is a methyl orange or methyl red, because not the free acid, but they are corresponding sodium salts are produced, because these are highly soluble in water, because most of these dye compounds will take in water medium.

So, this as well as different other organic chemicals, we can handle with the use of these particular reagents based on sodium. And it is also very much useful as coolant some other area the nuclear reactor. So, in nuclear reactors, we know one type of reactors are the fast breeder reactors. And those fast breeder reactors, we use the molten or the liquid sodium.

The molten sodium can be useful as a coolant, not that your water, not that of your any other heavy organic liquid, because they have the huge amount of evaporation effect like that of your glycerol or any other, so the metallic thing that means, the metallic sodium that means, the liquid sodium or the molten sodium can be useful as the coolant.

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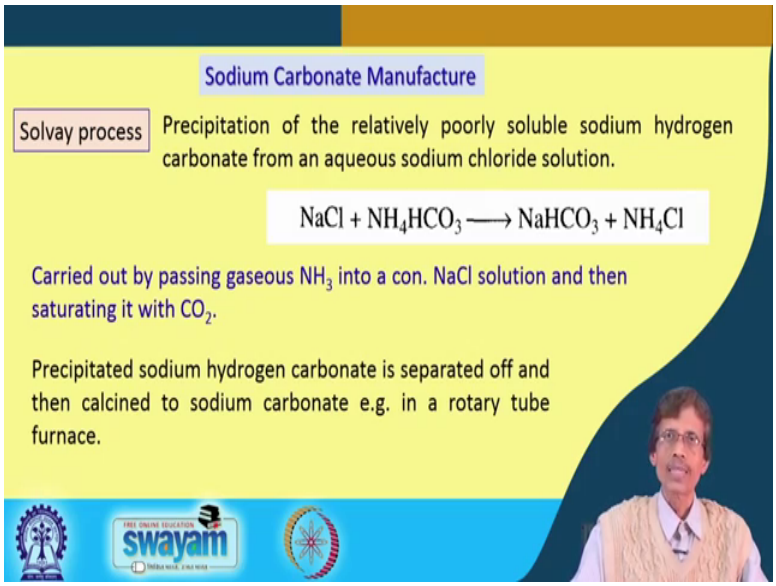

Then after this particular one, we can have some examples one or two, three examples, we will see. For the production of huge amount of some very industrially important compounds, we know that. A company is expanding like that of our in our country the Tata chemicals, they are investing huge amount of money say for the expansion of some industrial sector, what do you read in the newspaper that is the soda S or any other thing.

So, what is that soda S, so this is the technical term, but as inorganic chemist always we try to know, what is that compound where we get it, and how we can manage it to get from your corresponding source as your metallic element. So, how metallic sodium can give you, the corresponding production of sodium carbonate.

So, one of the process is very well known, and historically is also very important, because everybody should know starting from any chemist any chemical engineer or any industrially handling chemical compounds that what is that Solvay process.

So, Solvay process is there available, which is required for the production of sodium carbonate industrial manufacturing of sodium carbonate. So, if some question is asked that always you try to remember only that, it is the Solvay process, which is the most useful process for the manufacture on of sodium carbonate, it is not for other sodium based compound or not potassium based compounds or any other compound.

So, what we do, there is the precipitation of relatively poorly soluble sodium hydrogen carbonate. So, we take sodium bicarbonate from an aqueous sodium chloride solution, because we have seen that we have a huge source of sodium chloride from seawater from brine, so that sodium chloride in this molten condition was useful for the production of metallic sodium, now this can be used for the production of sodium carbonate.

So, what we do that we take sodium chloride and we use react it with sodium ammonium bicarbonate now, what the other element we take. So, if we take these reactions, so this is the corresponding metacritic reaction, because the ammonium bicarbonate will be converted to sodium bicarbonate, so that sodium bicarbonate is our starting material for the production of sodium carbonate nothing else.

So, initially we what we see that, you have this sodium chloride which is very readily available, which is cheaply available also, so that sodium chloride, so how will you convert. So, how Solvay process is responsible for converting sodium chloride for the production of that particular. Say if we consider that this is the important product for your soda S manufacturing, so how Solvay process is useful for production of your soda S from sodium chloride. So, we get sodium bicarbonate.

So, the reaction is carried out, how is not that direct addition of sodium bicarbonate? What we do we use gaseous ammonia that means, ammonia in the gaseous form whether it is industrially available or not, we have some good source of ammonia. So, the ammonia in the gaseous form is added to the concentrated sodium chloride solution and side by side you parch or you bubble carbon dioxide. So, what is happening is a very simple reaction.

But, industrially people do all these reactions is not that what we do in our laboratory test tube that we have the two components a and b; one a is sodium chloride and b is your ammonium bicarbonate. We mix them together, and we expect that we get c and d, c is your sodium bicarbonate and d is your ammonium chloride, but it may not happen all the time in such a fashion.

Because, if you add these two in the reaction medium in solution in water medium all of them will try to dissociate, so the dissociation will give you sodium ion, chloride ion, ammonium ion and bicarbonate ion is not that you will be getting sodium bicarbonate or the separation of sodium bicarbonate from the reaction medium. Until and unless, you go

for some precautionary measure for that particular isolation that means, we have to check for their solubility differences.

So, if the product thing that means, c and d have different solubilities, then only we expect that we will be able to separate them from fractional crystallization from the saturated solution of the saturated reaction medium. But, what about the addition of ammonium bicarbonate, ammonium bicarbonate we also not will just buy because the ammonium bicarbonate can be a costly chemical to us, which is not very much useful, if you try to get benefit out of industrial process.

So, in situ we produce in the reaction medium, whether we use some high temperature or some other reaction conditions that that when you parch ammonia gas along with your carbon dioxide in an aqueous medium. In situ we try to generate ammonium bicarbonate, so that ammonium bicarbonate will now directly attack your sodium chloride producing sodium bicarbonate, so that is why this particular Solvay process is useful in handling first your sodium bicarbonate.

So, now why we talk that precipitated one what is that precipitation? Because, you must have some difference in your solubility. So, ammonium chloride will be highly soluble, your sodium bicarbonate will be less soluble, so that is why from the saturated solution of the reaction mixture. When you expect that all the four salts are present, a is reacting with b giving c plus d, so what do you expect? In a huge industrial scale in a huge reactor, you have a, you have b, you have c, you have d. But, our goal is to get only the c the sodium bicarbonate, in pure form, in huge amount and in the solid form also.

So, we must have some recipe, we must have some procedure or we must have some manufacturing method that we should get only sodium bicarbonate in its purest form, so that sodium bicarbonate is taken away as its precipitated form. So, precipitated sodium hydrogen carbonate that is why is separated off then.

And is then again calcined that means, the high temperature heating. So, high temperature heating that which is known as calcination, which is known as the material has been calcined to sodium carbonate, where is a specially designed furnace, which is known as rotary tube furnace. So, if the question is asked to you that where we use rotary tube furnace, what is that particular method? So, the answer is very simple that it is the rotary tube furnace is for your calcination that means, the thermal degradation of sodium

bicarbonate is achieved in rotary tube furnace, in a process the whole process is known as your Solvay process.

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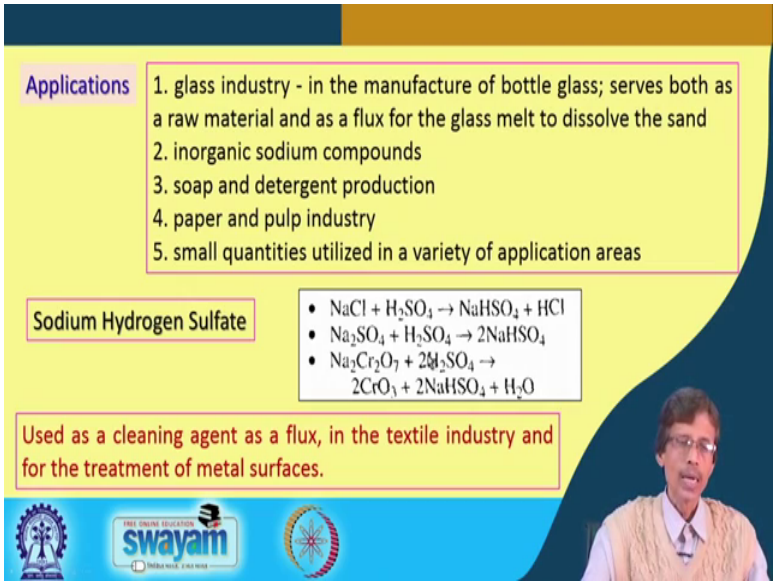

Then we find some applications that sodium bicarbonate is very useful compound. The soda S manufacturing everywhere we have the huge demand. So, nowadays also the existing companies, they are expanding for their soda S manufacturing, their monthly sorry your annual production in metric tons they are trying to increase.

So, the first application or the first utilization of sodium carbonate is your in your glass industry. For the manufacture of bottle glass serves both as a raw material and as a flux for the glass smell to dissolve the sand. Because, when we make the sand we know that silicon dioxide that Si O 2, the silica is consumed along with potassium oxide, sodium oxide or any other thing. So, it is basically a sodium silicate material. So, is a solid crystallized sodium silicate material along with other thing that means, you can have also.

Potassium silicate, so the source of that thing that means, sodium carbonate is given in this particular industry, because during the burning process, we are not utilizing sodium oxide that means, N a 2 O, we are not utilizing which is a pretty costly one. But, in a particular glass like that of your cement Portland cement, we try to write that this much sodium oxide is present.

So, the composition of a particular glass in a glass industry is reported in the form of the different oxides present, how much your silica is present as silica dioxide silicon dioxide Si O 2, potassium is present as potassium oxide K 2 O, sodium is present as N a 2 O. The way we also describe all these things, in case of your analytical data for Portland cement also. Those are also a mixture of the different types of oxides. So, is a oxide or silicon material, where the ingredient as sodium carbonate is used, because the sodium carbonate again during the burning process will give you the sodium oxide and carbon dioxide.

Then the different types of inorganic sodium compounds is very easy to get from sodium carbonate or bicarbonate, because one of the starting material of this particular methodology is your sodium bicarbonate and that sodium bicarbonate is giving you your sodium carbonate.

So, different types of inorganic compounds, if we try to use these as the corresponding compounds of sodium salt like sodium sulphate, sodium phosphate or any other complicated sodium salts, we always can use sodium bicarbonate or sodium carbonate, because this can also give you a typical acid base reaction. That means, if your benzoic acid is given, how will you make sodium benzoate? It is simply reacted with bicarbonate or carbonate, because for reaction with carbonate, you must have some typical procedure, because you have to apply some force to get it reacted with this particular one. But, bicarbonate reaction is facile one, immediately it is giving you a sodium benzoate form.

Then the soap and detergent production, because the sodium salt of fatty acids, we all know that they are the soap, and the sodium phosphates, and all other triphosphates and all the things are your detergent. So, there also we require sodium, because sodium we require everywhere. Then in paper and pulp industry, sodium carbonate and bicarbonates are required and small quantities are utilized in the various different application areas. For making a very small value added material or the specialty chemicals or the pharmaceuticals, we use these for your corresponding conversion to sodium.

So, one such molecule or one such compound is also your sodium hydrogen carbonate that means, the sorry a sulphate that bisulphate NaHSO 4, how we make that NaHSO 4. So, we just simply directly from a textbook any other textbook (Refer Time: 25:23)

textbooks, what we consider every time one of the book we are following and we are taking all these examples from that particular book that already we have seen how sodium chloride is consumed for the making of your sodium bicarbonate or carbonate.

Now, for sulphate is very easy again from sodium chloride, so sodium chloride is giving you this particular form that means, sodium hydrogen sulphate through the reaction is sulphuric acid. Similarly, if you have the supply of sodium sulphate also, that can also react with sulfuric acid giving you sodium bi-sulphate. So, making or the production of bi-sulphate industrially is very easy, you can get all these things very easily including a more difficult one or sometimes the corresponding one is available as your typical sodium salt of dichromate.

So, Na 2 Cr 2 O 7 can also be utilized and that sodium dichromate, when reacts with sulphuric acid is giving you chromium trioxide that we know from our school days from our early years that we produce chromic acid. So, in concentrated sulphuric acid, if you add a pinch of sodium dichromate, it you are getting the crystallized form of chromic acid. So, it is the process of making chromic acid, it is a chromic acid preparation which is a very good cleaning agent for your glass apparatus, cleaning the grease and all these thing, because it is a very highly reactive oxidizing agent chromium trioxide. But, along with that because it is precipitating out you can filter it out.

So, if a stoichiometric reaction is allowed between sodium dichromate and sulphates that means, there is sulfuric acid, you will be able to produce the equivalent amount of chromic acid as well as your sodium bi-sulphate, which will be remaining in the aqueous medium. So, aqueous medium shows filtration and the saturation of your aqueous medium will give you your sodium bi-sulphate.

So, this particular one, why we are talking why we are selecting some of them only, you are not going for the huge list. But, only some selected inorganic compounds, we are talking about how they can be produced in the different pathways or how industrially, they can be used, because they have useful applications. So, they are very useful as the cleaning agent as a flux material. So, anything can be cleaned with this particular one.

In the textile industry, it is also useful. And in the treatment of the metal surfaces the metal sulphate, so if you have some oily matter or the greasy matter on the metal

surfaces, so you can use that particular one, for the cleaning process with sodium hydrogen sulphate.

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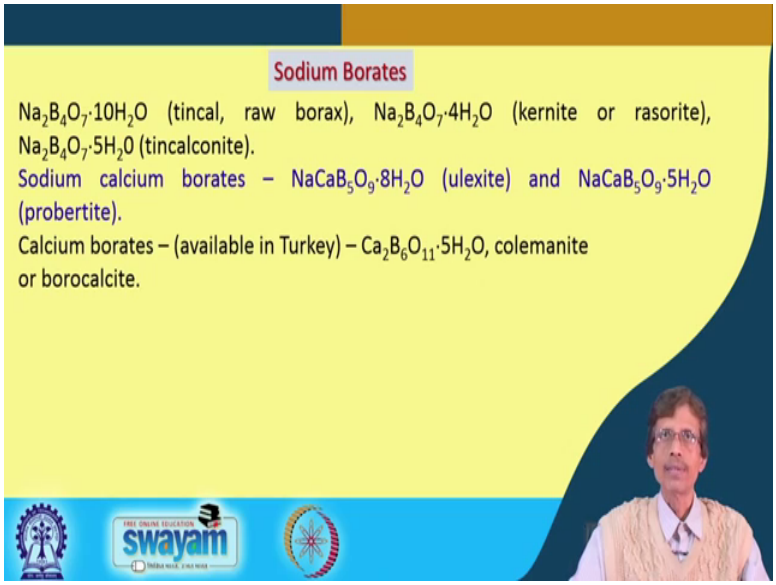

Then we will see that how sodium borates are formed. So, together with this class as well as the next class, we will continue this how borates are formed? So, what are the different types of borates you know basically, as we all know what is your borax, as because we basically know it very well, because it is a naturally available compound.

So, naturally available borax compound you have and the problem is that how you convert that particular one. The way we are talking all the naturally available material, all the naturally available your ore or the minerals for it is very useful compound.

So, first thing what we will see here is your Na 2 B 4 O 7 with a 10 molecules of water of crystallization, because these water of crystallizations the deca hydrate form is very useful, because otherwise you do not have that particular crystallinity in the molecule. So, molecules the inorganic salt will be crystallized in presence of those 10 water molecules in this particular form and which is also available naturally, because the in nature also.

Because, the moisture air everything is giving you the regular supply of that particular water molecules in your tincal, commercially it is known as tincal which is nothing but your raw borax material, which is your N a 2 B 4 O 7.

Then we can also have kernite, which is also known as rasorite in some other form. And tincal calconite tincalconite is also sodium salt of your B 4 O 7 salt, which is B 4 O 7 2 minus. So, this network of this borate form that means, four borate units are clubbed linked together, you cannot have one single boron center, you have four boron centers are together. And those boron centers are connected through your oxide links basically, oxides and hydroxides, terminal hydroxides giving you that particular tetrahedral arrangement or four boron centres giving you B 4 O 7 2 minus salt.

And depending upon your different content of your water molecules, whether you have 10 water molecules, 4 water molecules or 5 water molecules, you have different sources. So, varying from one country to the other or varying from one place of that particular country to the other, we can have all these different forms, because we all know that the ores and minerals are available in different forms and sometimes only in the difference in their water of crystallization.

Then we can have also the other material that means, the sodium calcium borates, we have, so these sodium calcium borates and also the calcium borates. So, all these together, we will continue this class do not worry for that, we will continue from this starting material, but only thing that you try to remember, because these are commercially important compounds is not that you apply your own brain to find out these things, because what is the difference between those formula basically, what are then calcium borates, and the calcium borates of different type.

So, borax and the different borates, you can have the different forms, the different structure of these compounds, which are also naturally available. So, those naturally available forms of these things, you have to convert them to sodium borates that we will see in our next class.

Thank you very much.