Industrial Inorganic Chemistry
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Lecture – 05
Water

Hello and welcome to this class of Industrial Inorganic Chemistry. Where we were talking about some of the basic materials such as water, hydrogen and some of the peroxides molecules, industrially important those molecules we will see today.

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So, as we are talking about the most important thing is Water for industrial point of view and this water we have seen that this can be utilized for different purposes. So, if we consider that the water can be utilized for some reaction for some solvent purpose to somewhere we can use this particular water as a catalyst that we have seen in detail in our previous classes. Today, we will see how we can get this particular water molecules or a very pure quality of water because it is important in many processes such that we can have a wide ranges of purification processes which can be developed in time also.

So, pure quality of water and some of these waters how we can utilized industrially that we will see and we have seen that we can have different processes where this particular molecule of water can be utilized for a reactant. So, what are those cases? As we have seen earlier that sulphuric acid production is also an important part where we can use or

utilize water for the reaction of sulphur trioxide. Similarly, during phosphoric acid production if we can have as we know from the very simple reaction that P 2 O 5, the phosphorus pentoxide when it reacts with water molecule it gives you a H 3 PO 4.

So, say phosphoric acid and related other acids if we can have the corresponding phosphorus based anhydrides where no hydrogen is present. So, basically we will be talking about these oxides and these oxides when they react with water molecule they can give rise to the corresponding acidic form. So, acetic anhydride can give us the corresponding acids in large scale because, the production of sulphuric acid production of phosphoric acid in large scale is very important for different other industrially important compound preparations.

Similarly, for the production of sodium hydroxymethyl sulfinate, we can use water for the introduction of as we can see from the name only that hydroxymethyl sulfinate function can be obtained from the water molecule present over there as a material which can be component of our reaction. Then we can have the chlor-alkali process which is nothing, but the electrolysis of sodium chloride and the by-product of that particular chlor-alkali process that we will see once again also during the electrolysis of NaCl we can get the use of this particular; that means, that sodium chloride electrolysis we have to use the water molecule present over there.

Then Ostwald processes, different other named processes like Solvay process, Ilmenite process and gold cyanide refining is also dependent on the water molecule, as well as the quality of the water molecule involved in those industrial processes.

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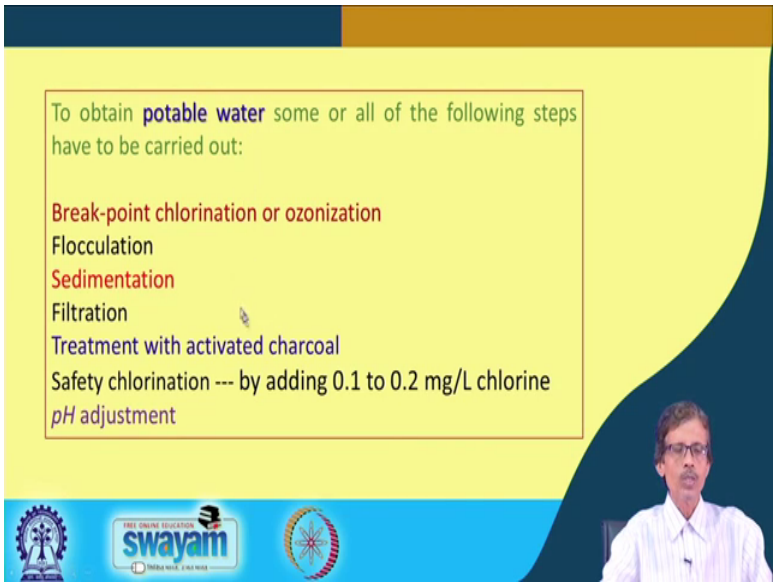

So, we will see now that how we can utilize these as well as some of the water molecule we can consume as a portable water molecule. Because, not all other water molecules starting from our sources from the seawater to the river water or the ground water molecule water level; we cannot get everything as a portable water; so, what are these difficult things what we can use to make the water portable or utilizable for our consumption. We can have several techniques one is the most important technique is the chlorination or ozonization.

The chlorination and ozonization is therefore, very important because it can kill the corresponding bacteria or the germs present in the water molecule; that means, also the some organic original molecules or some material which can be killed due to chlorination; that means, chlorine can also be utilized for the oxidation process. Then this particular water molecule can also be utilized for the flocculation; that means, if we can go for the typical coagulation; coagulation and flocculation can go side by side. So, flocculation process is the different flocks which can be combined together for different getting the different flakes and which can be separated out.

Then, for the sedimentation process; that means, some unwanted material or some unwanted part of these important things are also separated out as a sediment from the water molecule. So, if a water molecule which is very much muddy in nature we can go for it is sedimentation process and that particular sedimentation process can take up some

of the other inorganic salts such as sodium arsenate, calcium carbonate and all other thing which can be separated out and the 4th technique which is also very much useful is the filtration.

We can have different types of filtration processes and in laboratory as we all know the filter papers are utilized to remove some of the unwanted materials of these water molecules with from the water molecules and these unwanted species and sometimes we can have some precipitation also in a reaction. So, that precipitation or the precipitate from that precipitation reaction can be separated through a filtration process and depending upon the size of those particles watch is forming starting from our micro particles to the nano particles so, we can use different types of filter papers and the porosity of those filter papers are useful for separation of the different types of materials.

So, as we all know that separation of say calcium oxalate when calcium is getting precipitated through the addition of oxalate anions in a reaction medium we can have the corresponding thing. That means, we can have in our hand calcium oxalates and how to filter out those calcium oxalates that we should rely on some of the pore size of the filter papers similarly some other gelatinous product is our ferric hydroxide.

So, iron as we all know then that can be separated out in any determination or any amount of preparation of calcium sorry iron hydroxide addition of hydroxide ions through ammonium hydroxide or sodium hydroxide to a solution of ferric ion say, we get a very flocculus precipitation which is very light in material, but the particle sizes are very small. So, for those cases also we can use a different filter paper number we know that we can have Whatman type of a variety of filter paper is well known in the market. The Whatman filter paper 41, 40 or 42 we can use for different sizes of those particles.

Then, if we can have in other cases we can have some bigger particles. So, activated charcoal; that means, the charcoal; that means, basically a black carbon powder, so, black carbon powder which can be obtained from bone mass or the wood mass. So, if we can activate those charcoals by burning off some unwanted material which is adsorbed over that charcoal material, we can utilize that charcoal packed with some filtering column such that of our ion exchange column. So, packing of those column by charcoal we can utilize that particular packed column for filtration process where the bigger particles cannot pass through the inter particle passage of those charcoal material.

So, sometimes we just simply say that the treatment with activated charcoal can clean or can purify some amount of these water molecules such as some water molly water may water available to us is muddy in nature which is coloured also and which is also smelly. So, smell of that particular water and the colour and some suspended material can be removed if we can go for a filtration using charcoal. So, this can also give us some idea that how we can go for the treatment with some activated charcoal material.

Then, as we have seen chlorination and ozonization so, ozonization; that means safety chlorination. How we can go for safety chlorination; that means, we can improve the quality of the water molecules or the quality of the water which is available for some industrial purpose or sometimes we know that water can be utilized for the some swimming pool where we do not allow the for the growth of the bacteria or the fungus. Then we can add in these cases a very small amount of chlorine; chlorine either in a solid form like bleaching powder or passing chlorine directly from the cylinders.

So, at the level of 0.1 to 0.2 milligram per litter of water can be added for chlorination which is a septic chlorination because, if your water is little bit of alkaline in nature we cannot go for higher amount of chlorine. Because, the chlorine present over there can react with the hydroxide ions if it is slightly alkaline to give you some hypo chlorides or any other active material based on the chlorine. So, we should have very low concentration of chlorine which can only kill the germs, the organic matter, the dye molecules or some unwanted material which is still present in water.

Then, we finally, can go for pH adjustment because for all these reactions all these industrially important reactions such as the catalyst or some solute the water should be in neutral pH; that means, that in the range of pH 7. So, if we can have a water and if we find that the pH of that particular water is in the acidic side or in the basic side accordingly we have to go for acidification or addition of alkali or addition of sodium hydroxide or potassium hydroxide or sometimes very dilute solution of ammonium hydroxide can change the corresponding acidity of that particular pH. So, pH adjustment is also very much needed such that we can have a very useful amount of pH adjustment for moving that particular pH of the water to close to 7 to close to 6.8 or close to 7.2.

So, after this useful adjustment of pH we can have this particular water available to us can also be utilized as a solvent useful solvent because, if we can have this potable water

that potable water if it is a drinkable water also. So, potable or drinkable water can also be utilized for a solute in any kind of reaction water is directly utilized as a solvent or as a solute in some industrially important reaction which can go for immediate reaction with the water molecules.

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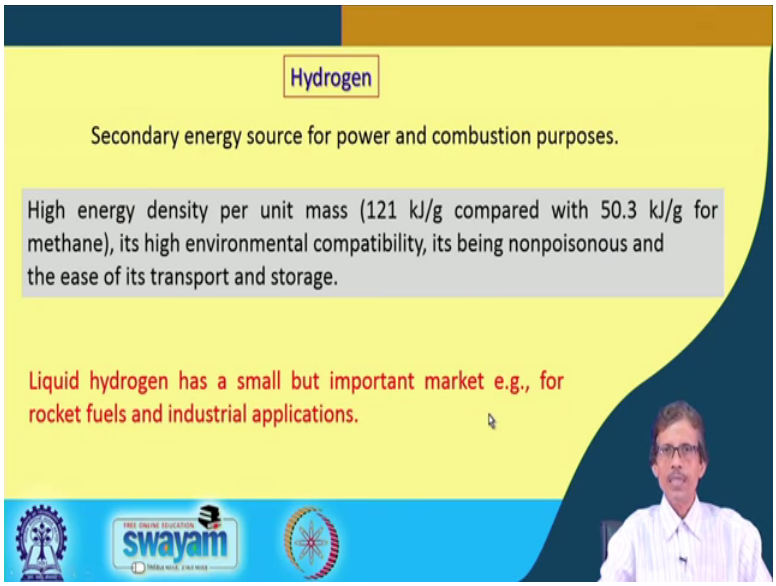

Then, if we can see that one of the component; that means, if we can go for the hydrogen out of these water. So, hydrogen can also be a very useful material from industrial point of view. So, the H 2, the simple H 2 molecule, how we can get this particular H 2 molecule so, the source can be in our hand is our water molecule. So, whether it is possible to get hydrogen from the water molecule or not that we will see now because hydrogen at the end also hydrogen is a useful material for the demand of it is this particular material or hydrogen gas as a fuel material.

So, hydrogen can be utilized as a secondary energy source because, day by day the fossil fuel the amount of fossil fuel what we can have still is reducing and we are consuming a huge amount of this particular fossil fuels the petrol the petrol's, the diesel and all other thing as well as the coal. So, we should always think of some secondary energy sources one of the important secondary energy source is the solar energy.

And, hydrogen can also be another alternative secondary energy source if we can have some technique where hydrogen can be utilized or can be obtained very easily rather in a cheaper way; that means, it should not have a very high cost for the production. So, we

can have this for power production for power as well as for different combustion processes because the hydrogen can also be utilized in presence of something where we can go for it is combustion process.

So, it can have this hydrogen gas can have a very high energy density per unit mass as we can see that it has 121 kilo joule per gram of the material which is very high compared to 50.3 kilo joule per gram for the methane. Which is the main component of our compressed natural gas what we are utilizing from our natural sources the petrol the petrol sources or the corresponding petrol what we get along with the petrochemical we get the corresponding CNG. So, if we just simply compare this particular methane as well as the hydrogen.

So, hydrogen will give you more energy and it is high environmental compatibility is also very important because it is non poisonous and is ease of it is transport and storage. Because, when we burn hydrogen in presence of oxygen or in presence of air it only gives you water molecules unlike your other fossil fuels based on carbon, based on carbon and hydrogen like that of your methane. So, when we have carbon in our fuel material the carbon what we can bond to carbon monoxide and carbon dioxide which can basically pollute our environment.

So, we cannot get rid of this particular components of carbon monoxide and carbon dioxide when we burn CNG or any other petro chemicals which are hydrocarbon based. So, the alternative for getting this particular source of energy is your hydrogen and it can have the corresponding availability for transport and storage because, hydrogen we can store it in the cylinders and those cylinders we can transport for some regular basis as we all know that nowadays we use the corresponding fuel as the LPG the Liquefied Petroleum Gas as well as the CNG all of them are coming in the cylinders. So, gas cylinders we are utilizing for all those cases the only thing will be we have to go for changing these two hydrogen cylinders.

So, the hydrogen gas cylinders can be the other alternative for this regular purpose and we can have some other safety point of view and other thing what we can see. But, before that we will see how we can get the corresponding production of hydrogen because, this particular thing can also be stored in a liquid form and this liquid hydrogen has a small, but important market. Therefore, because your petroleum gas, the petroleum

products, the petrochemical from the petrochemical processes is the LPG and that LPG the petroleum gas is also in a liquefied form then only you can go for transport of this material within the cylinder.

Similarly, liquid hydrogen can have some useful market and it can have also utilization for rocket fuels and different other industrial applications. So, when we can think of this particular thing that where we can use this hydrogen and hydrogen form rocket fuels to other industrial applications. So, as we have seen that hydrogen can be burnt away and that can be useful for fuel and also can be useful for the rocket.

Similarly, how we can utilize it for industrial applications? So, pure quality of hydrogen can be utilized for hydrogenation. So, hydrogen based economy can be developed when we do not have much of the oil source much of the coal source. So, post oil era what we can consider is that after oil what we can have as the energy source. So, during that period; that means, the post oil era we can have the hydrogen the alternative source of energy for the different purposes as well as from it is chemical point of view can also have some industrial applications.

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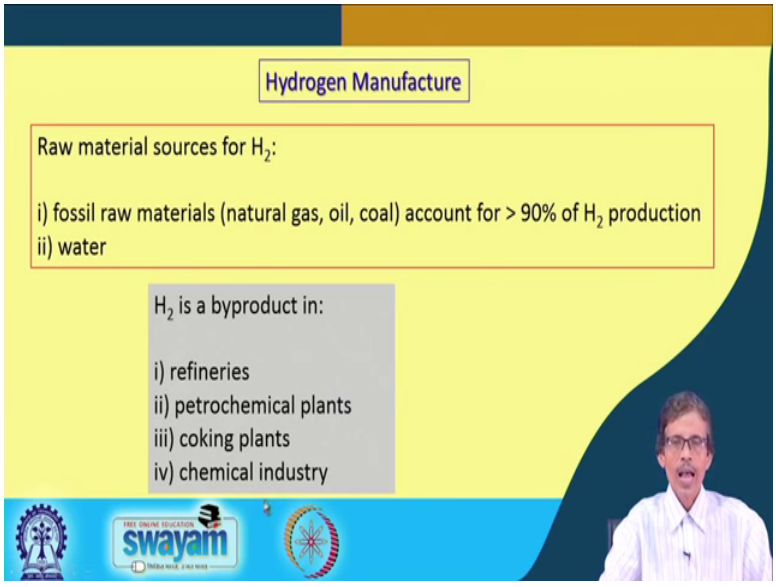

So, how we can utilize these; that means the hydrogen manufacture how we can manufacture these; that means, whether we can have the petrochemical process or the simple electrolysis of water. So, as we have seen just now that we can have the water

molecule and that water molecule can be utilized for hydrogen products and also. So, the electrolysis of water molecule can give us hydrogen therefore.

So, as we have just now seen that the raw material for the sources of hydrogen because the fossil raw materials natural gas, oil, coal all these we have seen that account for 90 percent of hydrogen production. So, all these material can be utilized for hydrogen production also because for electrolysis we have to use electricity and that electricity can be obtained from burning of coal. Similarly, we can get these from the water so, fossil raw materials which can be utilized for hydrogen production and water for the electrolysis.

And some other cases also not from the direct hydrogen manufacturing process; in other cases what we can have the hydrogen can be obtained as a by-product. As we have seen that it can also be a incidental by product for the chlor-alkali process; just now we have seen that for the chlor-alkali process where we can go for the electrolysis of the corresponding sodium chloride and in that electrolysis hydrogen can be H 2 can be obtained as a by product along with your Cl 2 and sodium hydroxide.

So, during electrolysis of sodium chloride we can get chlorine production, we can get sodium hydroxide production as well as a typical or very interesting by product is our hydrogen. Similarly, in other cases also that hydrogen can be a by product in petroleum refineries, different petrochemical processes and different petrochemical plants coking plants because the classification of coke and coal can give us hydrogen also and the different chemical industry.

Just now we have seen that for the electrolysis of sodium chloride because sodium chloride when getting electrolyzed with presence of water it give you sodium hydroxide, chlorine as well as your hydrogen.

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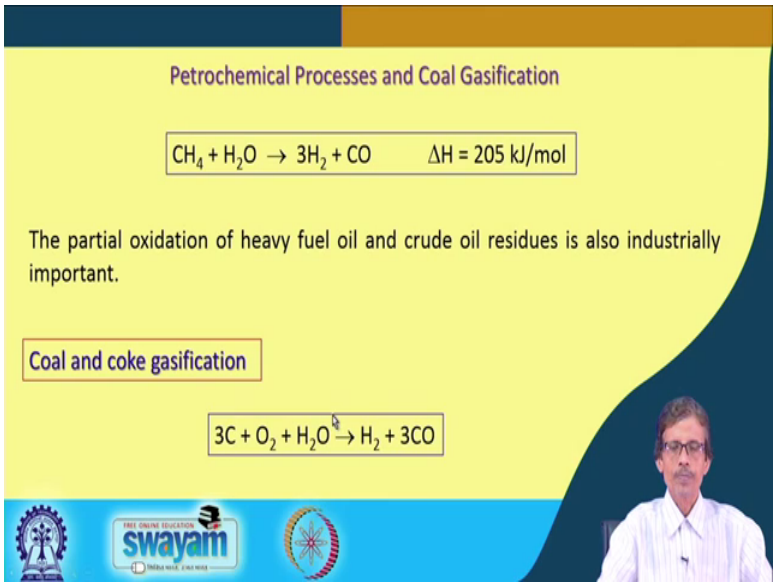

So, this hydrogen production from petrochemical processes and coal gasification can give us that production of hydrogen; that means, that if we can have the corresponding gas. The main component of CNG is the methane and when it is oxidized by water molecule it give rise to the corresponding production of carbon monoxide and hydrogen with energy value of this particular delta H value for this reaction is 205 kilo joule per mole.

So, this can be a very useful reaction for the production of hydrogen. Only thing that you have to take away the carbon monoxide produced or we can utilize this carbon monoxide for further oxidation to carbon dioxide. So, the partial oxidation of heavy fuel oil and the crude oil residues is also industrially important. So, oxidation of heavy fuel oil because all these fuel oils will know that they are all hydrocarbons.

So, compared to this particular hydrocarbon, so, these other hydrocarbons or the crude oil residues can also be oxidized for the production of hydrogen from there. Because, this particular reaction this production of hydrogen from methane; that means, whether you can have a supply of compressed natural gas or nowadays we are getting some methane from coal beds.

So, CBM we call the coal bed methane can also be utilized for the production of this hydrogen, because this hydrogen production can be industrially important for the direct production of the ammonia molecules. Because, nitrogen from air we can take and that

nitrogen can be reduced with the use of this hydrogen what is produced from methane for the production of ammonia first or further production of the urea molecule. So, fertilizer industry is also very much dependent on this particular production of this hydrogen.

Then coke or coal gasification reactions; so, coke and coal gasification reaction tells us that instead of burning methane type of thing we can have the corresponding carbon burning process. That means, the carbon should be oxidized and gasification is that the corresponding things whatever we are getting like that of your burning of your methane molecule, here we are also getting hydrogen and carbon monoxide.

So, oxidation of heavy fuel oil and this particular oxidation of a heavy fuel oil is also we can have because only thing as that we can have the corresponding other hydrocarbon which is Cn H 2 n plus 2 type hydrocarbon and that hydrocarbon can be oxidized to get different number of hydrogen and as well as carbon monoxide. So, this particular coal gasification process can also give us some idea that how we can utilize the fossil fuel the crude oil residues and all these thing for the production of hydrogen.

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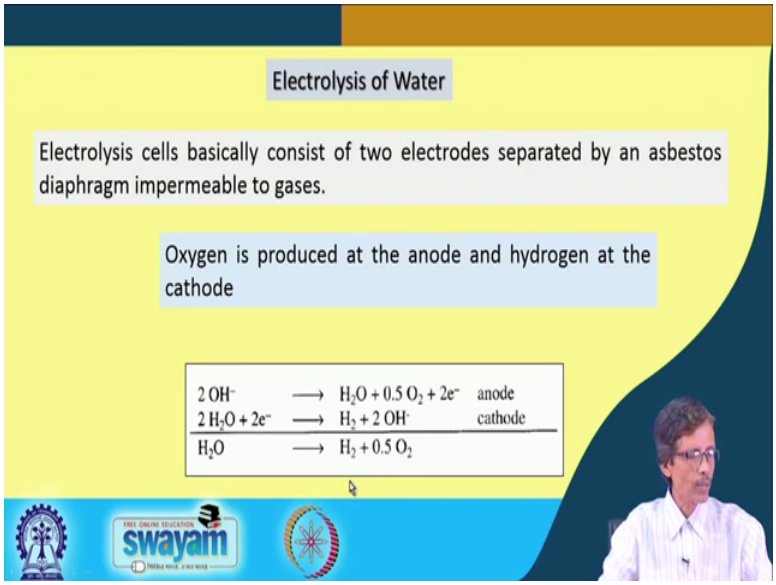

Then, we can see that how we can go for the electrolysis of water. So, electrolysis of water basically we can have some electrolysis cell which can have two electrodes and separated by asbestos diaphragm which is impermeable to gases. Because, the electrolysis during this particular electrolysis we have the products which are gases.

Hydrogen is a gas and oxygen is also a gas so, we can have the separated electrodes by the semi permeable diaphragms.

Oxygen therefore, is produced at the anode and hydrogen at the cathode. So, we get it through those reactions at the anode and the cathode. So, these reactions what we get that the anode for this particular one, the anode where the oxygen is produced whatever reaction we can write for the electrolysis is from the corresponding hydroxide ions also. Because, if we go for corresponding changing the corresponding pH of the water we can have these alkaline mediums, otherwise we can have also the plenty of hydroxide ions. Hydroxide ions when remove electrons to the anode it gives you the corresponding production of 0.5 molar of oxygen.

Similarly this water molecule when takes up two electron it gives you hydrogen as well as the hydroxide ions back. So, at cathode hydroxides are regenerated and those hydroxides are utilized for anode oxidation. So, overall what we can have? Overall your water molecule is utilized for the production of hydrogen as well as oxygen.

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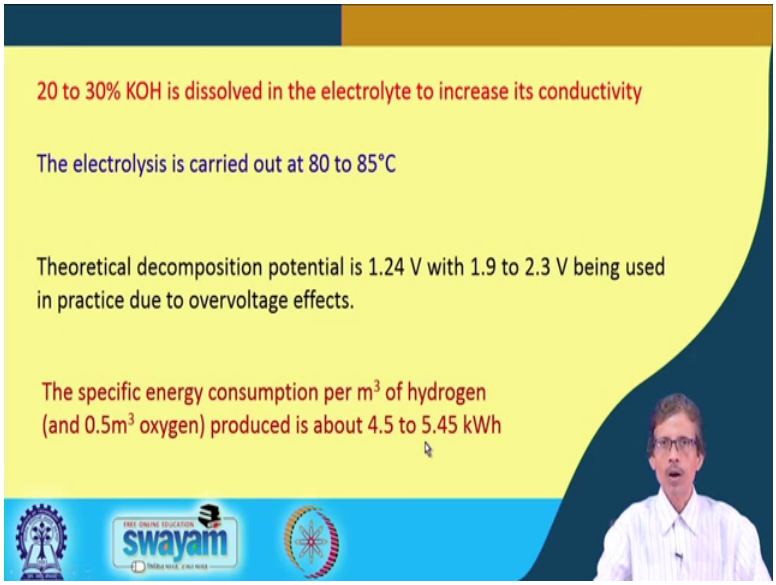

So, this electrolysis therefore, give us something where we can get these this production. So, just now what we have seen that the production of this oxygen from hydroxide ions how we can get that this can be achieved by addition of KOH. So, 20 to 30 percent of KOH is dissolved as an electrolyte because it also increases the corresponding

conduction the electricity conduction to increase it is conductivity also. The electrolysis is carried out at 80 to 85 degree centigrade because we are producing gases.

So, this temperature is also useful for the production of those gases and the theoretical decomposition potential because it can be different it can be little bit higher because we can have the over voltage effects. So, decomposition potential is 1.24 volt with 1.9 to 2.3 being used in practice due to over voltage effects. So, due to over voltage, we have to use some amount of higher potential value which is 1.9 to 2.3 volt for the electrolysis process.

The specific energy consumption per meter cube of hydrogen or 0.5 meter cube of oxygen because, when two molecules of hydrogen is produced one molecule of oxygen is produced from that particular reaction. So, energy consumption the specific energy consumption for this is about 4.5 to 5.45 kilowatt hour, because the energy consumption is the most important part for this electrolysis process whether it is industrially viable or not that will be dictated by the amount of energy which is being utilized.

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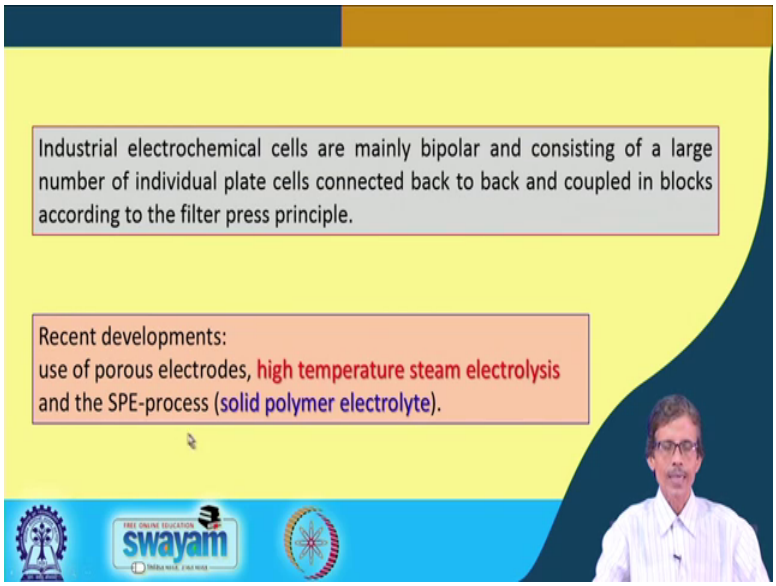

Thus we see that industrial electrochemical cells are we can have they are mainly bipolar and consisting of a large number of individual plate cells connected back to back and coupled to block according to a filter press principle.

So, these are technical things. So, these technical things are utilized for the typical industrial electrochemical cells because the industrial electrochemical cells are completely different from the cells what we are used for laboratory purpose. For that particular case what we can use their porous electrodes; that means, those are gas permeable electrodes. So, these porous electrodes are very much useful for this electrolysis of water, for the production of hydrogen.

Then high temperature steam electrolysis this another technique where high temperature beyond 80 to 85 degree centigrade can be utilized and SPE-process is the latest technique where we can use Solid Polymer Electrolyte. So, these are the different techniques what can be utilized for the electrolysis of water molecules for the production of good quality of our hydrogen.

Thank you very much.