Concepts of Chemistry for Engineering
Professor Arnab Dutta
Center for Distance Engineering Education Programme
Indian Institute of Technology, Bombay
Lecture – 57
Corrosion

Hello, welcome to the final segment of the application of the thermodynamics. So, far we have discussed the basic properties of thermodynamics; the first, second and third law of thermodynamics. We have discussed the important parameters enthalpy and entropy and free energies.

And then we jumped into the application of it, where we have discussed the Gibbs free energy and its connection to the electrochemical potential. Then we have discussed the equilibria during an acid-base and a solubility. And now in the final part we will discuss about the corrosion; so, let take a look into it.

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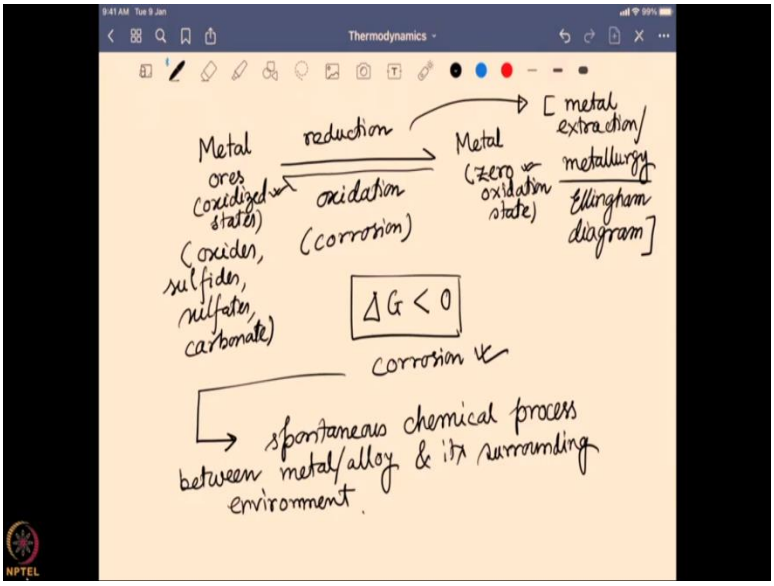

So, generally the metals present on earth, we generally found in the form of metal ores. We rarely found metals already present in their metal forms in zero oxidation state. Generally, they present in the metal ores, where they are in their oxidized forms; whereas, in the metal they generally present in their zero-oxidation state.

Now, if we want to use a particular metal for a particular application, generally we want to have it in the metal form; so that we can mold it as per our need to form different kind of compounds. And that is why one particular reaction always come into the picture, where we take the metal ores and produce metals.

And over there because it is from oxidized state, I want to come to the zero oxidation state; I have to do nothing but a reduction. And this process is actually widely known if we do that in the industrial scale as metal extraction, which is nothing but a part of the metallurgy. And we can discuss about more details of this metal extraction from its oxidized ores to the low oxidation state metal forms in the form of Ellingham diagram. And that part will be discussed in a different segment; so that is the reduction part. Now, what happens if I keep the metal present in the atmosphere? Is it going to stabilize it in its zero oxidation state? Most of the time not.

They actually react with the atmosphere and come back it gets oxidized. It oxidized back to its original ore state; and this is actually known as corrosion. And in the oxidized state in the metal ores, they are nothing but we can say metal salts or metal oxides. Where, they have oxides, they have sulphides, they have sulphates, they have carbonate to name few of the anions that actually binds with the metal and stabilize it in its oxidation state, higher oxidation state. And this metal corrosion is spontaneous process; so that is why corrosion occurs on its own in the presence of atmosphere.

Now, we will go and take a look into it; why we should care about corrosion? And try to understand a little bit on the details of this corrosion process. So, as we just discussed corrosion can be defined as a spontaneous chemical process. We are saying it is a chemical process, because there is a change in the chemical form is involved here with this oxidation state of the metal is changing. So, it is spontaneous chemical process between a metal or in its alloy, where the metal is still present in its metallic form even in the alloys, and its surrounding environment. So, this process is known as the corrosion. So, what is an example of corrosion?

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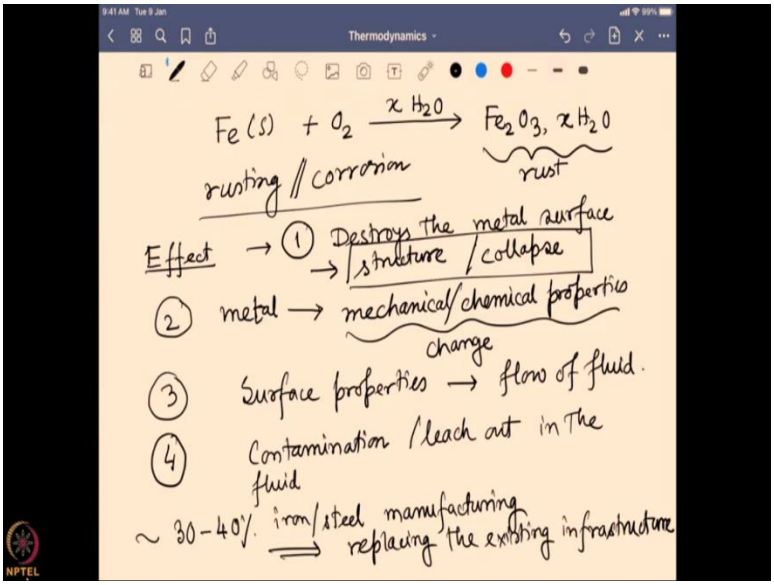

So, one most common example is if we take something made out of iron in solid form, and once it is exposed to aerial oxygen and water molecule present around in the form of humidity; it produces the iron oxide bound with water, and this is known as the rust. So, rusting is nothing but a corrosion process; so, why do we care about corrosion?

Because corrosion is a very destructive process; so, corrosion the effects are it is a destructive process. So, it actually destroys the metal surface, and metals are used in a lot of constructive works all around the world. So, if the metal surface is destroying and it will affect this overall structure; we are going to see a collapse in the overall structure.

So, that is going to weaken all the metal present in all the infrastructure we are using; and that can have a huge effect on the long-term durability of the buildings or all the other constructive materials. So, that is why we need to understand the corrosion, and try to prevent it if possible.

Secondly, the metals have a particular property in its metallic form at zero oxidation state. Once it gets oxidized, there is a change in mechanical or chemical properties during this corrosion. And this change in the mechanical or chemical properties is going to affect the overall activity of the metal, previously, when the metal is present in its original form or in the form of alloy.

And once it gets oxidized, it may not show the same property again. And that is going to affect the applicability of that particular system. Third: as we just discussed the surface properties changes

once the corrosion is started occurring. And that is going to affect the flow of fluid through that system.

So, a lot of metal systems are used as pipes, where we use for the flow of water, flow of gases, full of different petrochemical products. And that flow of that particular fluid is very much dependent what is present on the surface of these pipelines. And if they are getting rusted, their properties are changing that flow is going to get affected; and there is a possibility of different accidents may happen. So, in industrial scale this why corrosion is actually a huge problem.

And last but not the least during the change of this oxidation state, there is a possibility of contamination during the change in the oxidation state when the metal gets oxidized. It can leach out into the pipelines, into the fluids that is flowing through that. And as human beings or other animals and biosphere is constantly connected to that; the whole biosphere is exposed to that contamination.

And if it is a toxic metal, then it is very bad. For example, this lead poisoning happen, because of this lead pipe is leaching some lead into the water. So, all these problems are showing us that the corrosion is a phenomenon that is going to occur anyways. But we need to know how to control it and how to prevent it.

And nowadays I am just to give you an idea how corrosion is important; 30 to 40 percent iron and steel that we are manufacturing today. It is actually used for replacing the existing infrastructure. So, now you can have an idea that the overall iron and steel that you are using how prone they are for this particular corrosion.

And because we cannot go without iron and steel, we are going to replace it; and almost half of it, a little less than half of it; it actually replacing work all the time. So, it is showing the influence and the long-term effect of corrosion in real life. So, now take a look how the corrosion occurs?

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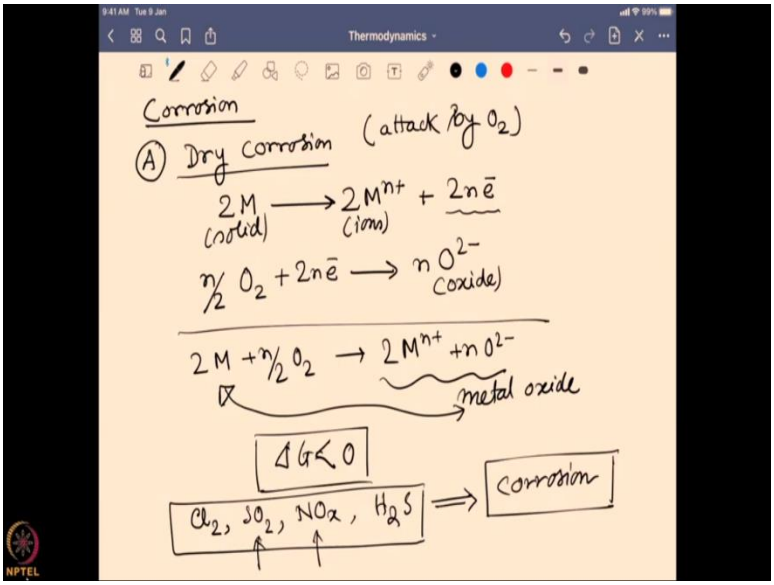

So, the corrosion occurs in two different ways. The first is known as the dry corrosion; so, I am taking the example of attack by oxygen. So, oxygen is present in nature in the air almost 21 percent is a strong oxidizing agent; and it will like to oxidize a metal present in its low oxidation state. So, what happens say metal is there present, it is getting oxidized; and it is giving electrons.

So, from a solid metal, it is giving me ions. And once it is getting to ion that means there is a change in the overall structure, you started corrosion. And how the reaction is supported? The reaction is supported by the oxygen. So, the oxygen takes those electrons evolved from the oxidation, and act as a sink for them and produce the oxide ion.

And these oxide ions are going to play together, and if we draw these reactions together; what I am going to get is the following. And these two can come together and form the metal oxide. And that is why from a solid metal I am going to get a metal oxide; and this reaction is favored due to the -ΔG value of this reaction, because this oxidation process. And that is why this full process is a spontaneous process; because ΔG is negative for this particular reaction. And this is happening in the dry condition in absence of even any liquid or water present there; the directly the aerial oxygen can attack a metal and do that.

And not only oxygen present in air can do that; there is also some other strong oxidizing agent like chlorine, Sulphur dioxide, nitrogen oxide and even hydrogen sulphide can also play a role; and affect or trigger the corrosion of a metal. And these gases are always present in atmosphere and

especially in the industrial scale. Near to the industry we are producing a huge amount of this particular gases; especially the Sulphur and nitrogen based oxides. And those are actually acting as an oxidizing agent to degrade the quality of the metal to initiate the corrosion process. So, that is what is happening during the dry corrosion.

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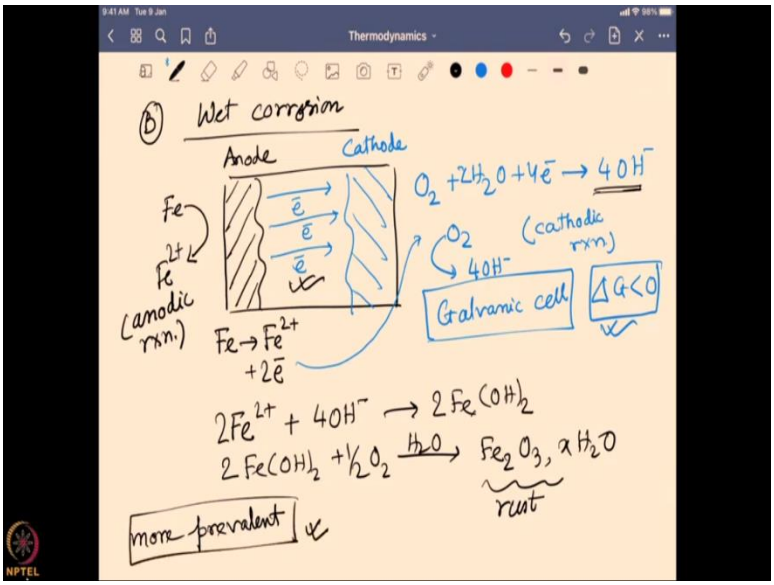

There is another process also happens at the same time, which is known as the wet corrosion. In the wet corrosion process, as it is quite obvious from its name; now the liquid or water has to play a big role. So, now say, I have an iron container and this iron container creates two different phases.

In one particular part the iron started getting oxidized; and on the other part the oxygen is taking the help of the electrons coming out of the system in the presence of water, and creates hydroxide ions. So, over here what is happening? If you remember the electrochemical cell, it is quite similar to that. Over here iron is getting oxidized, so it is nothing but an anodic reaction. So, this part of this vessel is acting as an anode.

Whereas, oxygen is coming on this side and producing OH^-; so, which is nothing but a cathodic reaction or reduction of it, oxygen is getting reduced. And this is nothing but you can say the cathode section of the system; so, it is nothing but creating an electrochemical cell. And over there the vessel itself carries the electron through from one side of the anode to the other side the cathode. And this reaction happens way too fast, because it is nothing but creating a galvanic cell basically;

and over there the ΔG is negative. So, the thermodynamics support it, and altogether we are going to see this following reaction.

So, $2Fe^{2+}$ is reacting with $4OH^-$ that is created during this reaction; and going to form iron hydroxide 2 $Fe(OH)_2$, where iron(Fe) is in +2 oxidation state. Now, iron in +2 oxidation state when it is forming hydroxide; it is very much vulnerable for further oxidation. And in presence of water, it creates nothing but rust ($Fe_2O_3.xH_2O$). And this process is very spontaneous, very much feasible, and happening all the time with iron bound system all around the world. One of the prime examples of that is the ship corrosion. In the large ship or vessels, the most of the ship outside interior is designed with iron.

And when it is exposed to water when it is hitting the sea, it is exposed to water and vapour and humidity; it is reacting with the aerial oxygen. And in the presence of high salt concentration which makes sure this electron transfer happened way too fast, it is creating this wet corrosion very fast; and that start corroding the outside of the ship.

So, unless we put a protective layer on the outside, it is going to corrode the ship in no time. So, that is why you can see any iron system present very near to a water body gets corroded very easily, and produce rust. That is because this process is thermodynamically very favourable system and that is what is happening.

And if we want to compare between wet corrosion and dry corrosion; wet corrosion is a much more common process. So, we can say it is more prevalent compared to the dry corrosion process. So, that is the part; we will stop over here as a final example of the application of the thermodynamics. Thank you.