

Inorganic Chemistry of Life Principles & Properties
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Lecture – 01
Overview of inorganic chemistry of life

So, good morning, welcome you all to this course on the Inorganic Chemistry of Life Principles and Perspectives. First of all let me bit introduce myself my name is C P Rao, I am a professor in the Department of Chemistry, Indian Institute of Technology, Bombay. I am in the area of inorganic chemistry, bioinorganic chemistry, inorganic materials and inorganic related aspects of various things and connected even to those of the biological systems as well, ok.

First of all let me let us take up a query what do one understand from this title at all.

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Inorganic Chemistry of Life *Principles & perspectives*

What do one understand from this title?

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So, when you look at his title the title has as a word like life and life means we have various forms of life and this various forms of life you as we see around us. We have life in the form of plants, life in the form of animals; life in the form of in aquatic organisms, life in the form of human and variety of this life is there. And we know even from very early day school science studies that in every life the chemistry plays an important role. What additionally that we I would like to tell in this particular thing is, its chemistry

which is being supported by inorganic ions and inorganic elements is the one which is playing an important role.

There is a great emphasis by the inorganic species and ions which control various forms of the life processes, in other words the chemistry of life. So, it is this aspect that I would like to bring to your notice in the form of this particular course on inorganic chemistry of life principles and perspectives. So, let us look at for a while how this change the title how I have taken this inorganic chemistry of life as a title that suits for this particular course, ok.

So, if you look back into the history and even if you even in your the high school studies or degree studies, I am sure you must have been talked about that, there is a biochemistry that goes on in body in the cells everywhere. And in the early 60s people have formed that, there are some inorganic elements, which tend to influence the biological processes biochemical processes etcetera.

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Inorganic Chemistry of Life *Principles & perspectives*

How did I arrive at this title?

- 1960s - Inorganic biochemistry
- 1980s - Bioinorganic Chemistry
- 2000 - Biological Inorganic Chemistry
- Current – Inorganic Chemistry of Life

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And it is what the biochemist have started utilizing this and they have started using inorganic species just supplement support etcetera. So, therefore, they called it has a inorganic biochemistry.

So, it is a biochemist interpretation of the inorganic role in the biological studies is by inorganic biochemistry. And this is continued for almost two decades and so, from 60s to

80s where people have started worrying about what exactly is the role of these elements, and that is where actually the inorganic chemistry jumped into the area of this chemistry and started looking at the more details how and inorganic iron or species is influencing the chemistry in the biological context.

And they started probing in terms of their role, in terms of their function by various aspects of this. So, therefore, therefore, this has got into a kind of a area called the bioinorganic chemistry, where inorganic chemistry have started interpreting the biochemical aspects influenced by the inorganic elements.

So, therefore, and then this continued for quite some time then the scientist have realized, the kind of an inorganic elements are not just limited to the limited to the enzymes alone, but they are extended to various other components are the biological system. For example other biological molecules such as DNA, carbohydrates, lipids all these have certain kind of an influencer interaction by the inorganic elements.

In addition people are also formed the cells, you know tissue organs also have got a role of inorganic elements functioning in them. So, therefore, all this together it has broadened from simple bio inorganic chemistry to a biological inorganic chemistry where in the role of not only the inorganic chemist, biochemist, biological chemist and spectroscopist and the microscopist. So, variety of the, you know scientist need to you know support all this activity. So, therefore, this biological inorganic chemistry is indeed a very highly interdisciplinary in nature.

But being inorganic chemist by myself, so I would be mostly confining myself to the inorganic chemistry aspects in the biological processes, biological systems etcetera. But still I have taken my course title is inorganic chemistry of life because the inorganic elements role is found now, even in a variety of medicinal aspects as well. Organs and transparent tissue material so, there are many bio materials also having inorganic chemistry.

So, therefore, to encompass not only the enzymes and the biomolecules to encompass all these kinds of processes, so therefore, I have chosen now a title that to comprise of all this plus the other aspects of biomineralization biomaterials you know organ, synthetic organ etcetera all put in together it this company in organic chemistry of life. But with the limitations of the course I can only gives certain level of principles and certain these

principles will be highlighted through certain kind of a perspectives. So, therefore, the title of the inorganic chemistry of life is very apt and well suited for this particular kind of a course to talk about the inorganic chemistry aspects.

And one another aspect that I need to tell you at this stage is that the same course can be taught by a biochemist, can be taught by a biological chemist, can be taught by an inorganic chemist can be taught by a spectroscopist.

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Inorganic Chemistry of Life *Principles & perspectives*

A protein that transports oxygen to all organs of the body through blood

Inhaled oxygen (O_2) enters the bloodstream

Lung

Alveolar space

Red blood cell

Hg, HgO_2

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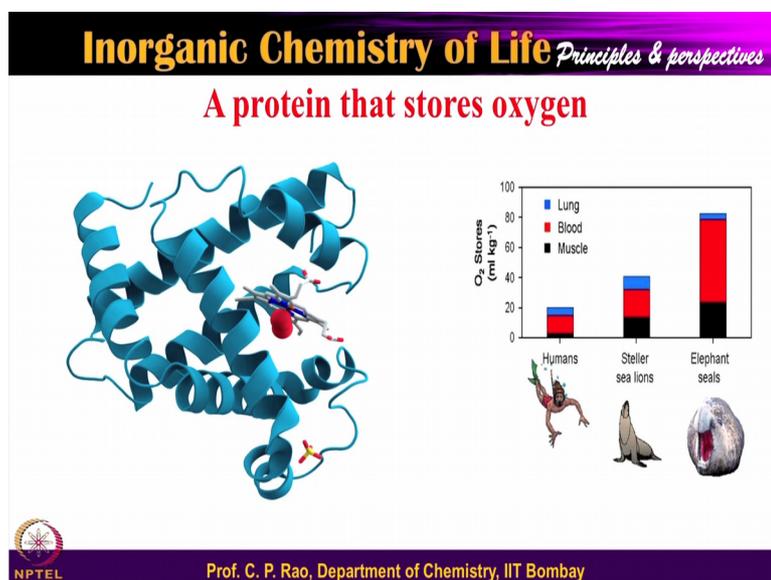
But taking the real examples, let us take the real examples and try to look at that. One of the example that I have taken in this particular slide is that the protein that carries the oxygen, and it carries through the blood and it carries to the all the organs of the body and through this. So, this particular protein is known as the hemoglobin in when you refer to the human system. So, you know the oxygen is required for every life. So, the respiration processes where the lungs are involved and then this lung pumping the oxygen and then the oxygen being transported by this protein across the different organs of the body through the or through the blood and that is what I would like to sort of highlight this, ok.

So, this has got two different things one is this spiral kind of a system, rebel like structures this is coming from the protein and there are some components here. The components here is the heem, which is heem is nothing, but the ion with a (Refer Time: 08:40) and this one such here then one more here, then one more here, and then one more

here. So, there are 4 such units are there therefore, this is referred as the tetrameric protein. And at each protein the iron centre is important because it is the iron center which will hold the oxygen and which will transport and which will release to the organ ok, in the body.

So, therefore, this protein is functioning by the inorganic elements. And we will look at the more details how it is functioning etcetera at a little later stage. Right now my emphasis is to convince you that the inorganic elements of heroes. So, the heroism of the inorganic element can be seen as in this case by sitting here in the heme portion and then followed by the other aspects of it, ok.

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Let us look at another example. It is not only transport in the oxygen obviously, the oxygen is also store oxygen is stored in human; oxygen is stored in sea lion oxygen store in other kind of animals elephant, seals, etcetera ok.

So, these are stored in various parts of the body like muscles the blood and lungs and you can see corresponding the ratio of that. So, the human you have total storage is somewhat less and the stories in the sea lions is at least twice on the story is oxygen is much more in the elephant seals, is at least 4 times to what we have in the human, what do you think is reason. I am sure you must have been thinking the size of the human size of the body.

So, size of the body in the human where size of the body of the sea lion versus the size of the body of the seal, obviously, required more and more when it comes to the elephant seals and that is the reason why you require more stories therefore, you have the more pumping later on into that too. So, this is again a protein like the earlier one and you have a ribbon like structures etcetera here you can see very clearly this is the iron centre, and this is the heme part of it and the whole thing is called the myoglobin when it comes to the human system myo refers to the muscle, so, therefore the muscle storage of the oxygen; so, therefore the myoglobin part of it.

And this if you compare with the previous one here you could see the four such units one blue here one red here another blue here another red here; totally four are there and if you look at here you have only one such. So, it is basically one-fourth of this. So, when you have a one-fourth of a protein its acting like a storage and when you have a tetrameric protein its acting like a transport.

So, I will explain this and much later stage not at the stage now. How can I 4 times same protein can behave differently. So, keep that as a anxious query which I would be explaining may be several hours later in this course not now, maybe at least 10th one lectures later in that.

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Inorganic Chemistry of Life *Principles & perspectives*

Enzyme that transports iron to all organs of the body through blood

The slide features a ribbon diagram of a protein structure with a central iron atom (Fe) coordinated by a heme group. To the right is a bottle of Sundown Iron 65 MG supplement. The bottle label includes the text: "Sundown Iron 65 MG (125 mg Ferrous Sulfate) Helps Maintain Energy Utilization Promotes Red Blood Cell Production".

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Let us look at one another example, ok. So, you know that the body requires a lot of iron. So, where why body requires a lot of iron? Body requires a lot of iron because as we

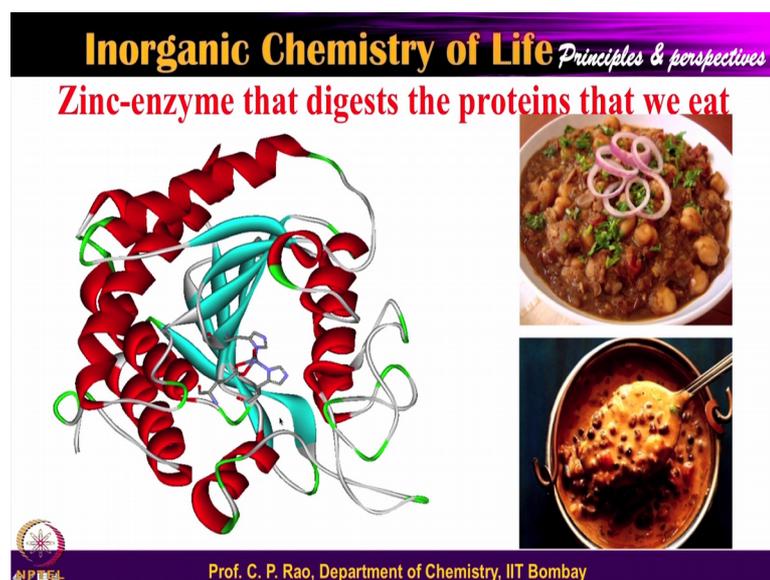
know there are large number of iron based enzymes in our body. So, therefore, a lot amount of iron is required. So, this iron being to be need to be transported to each of the organ of the body. So, therefore, that is done by an enzyme which is shown over here and this transport the transports the ion ions across the across the body, across the body through to various organs of the body. And here again you see that you see that the ion is sitting somewhere here the blue centre at then you have protein, protein having ribbon like structures, spirals and then flat regions etcetera which as I promised you I will come to this at a much later stage maybe after a two three hours of explanations of this, ok. But nevertheless I will certainly explain.

At this stage what I wanted you to understand is that there is a metal ion called ion, the ion is sitting inside the core of the protein and this particular protein takes this ion across the blood and transports to the various organs of the body. When you have a less amount of ion in your blood which you come to know by various test, various clinical test then you can have some supplement. The supplements ions are variety of ions supplements are available today I will explain also this when we come to the ion story when I explain you the about the ion story.

So, right now you need to know that the ion is present in the protein in the middle of the proteins in some core. I will explain this core more detail later stage. So, now, you understand there is a huge protein is a small inorganic ion. So, do not try to underestimate the small ion with respect to this. You know that the protein molecular weights are generally in several kilo Daltons maybe some 10, 15, 100, 1000 Daltons whereas, ion you know only 57. So, you have so much of difference in the weight that does not mean that the ion is can be ignored so, but ion place a very important role as a mentioned earlier the heroic role of the ion is being played by this particular element.

So, for the time being just take that the iron is present in this and the total protein as a constituent of that. Not simple constituent of sit to sit alone, but to function in this particular for the transporting the ion ions.

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Look at another example you know that I am sure from general knowledge that we know that our body has lot of proteins, ok. Also we know that we eat a lot of protein based stuff and you can see here on this right side on this slide you have all these protein based stuff.

Is the protein that we have in the body is the protein that we eat. If you were to think so, it is wrong. So, the protein what we eat, and the protein what we have in the body are quite different. So, we, but to have to make this protein in the body you need these proteins, which means the proteins that we eat are not directly converted as the proteins as the body requires to go through some process. So, this process is referred as the digestion process also known as the hydrolysis.

So, the protein has got peptide bonds, and the peptide bond can be hydrolyzed. So, these when you hydrolyze the peptide bonds what do you get you get amino acids. So, therefore, you have amino acids coming up. So, it is these amino acids which are picked up the by the body and use these amino acids again and make the protein what is required. So, the protein that is required by the body is synthesized in the body, but by using the protein that we eat not directly, but after hydrolysis.

So, who does this hydrolysis? So, that is done by enzymes called peptidases. So, one example shown here is the carboxy peptidase, in this you can see here that there is a ion is sitting over there and bonded to certain things which I will come back to you later

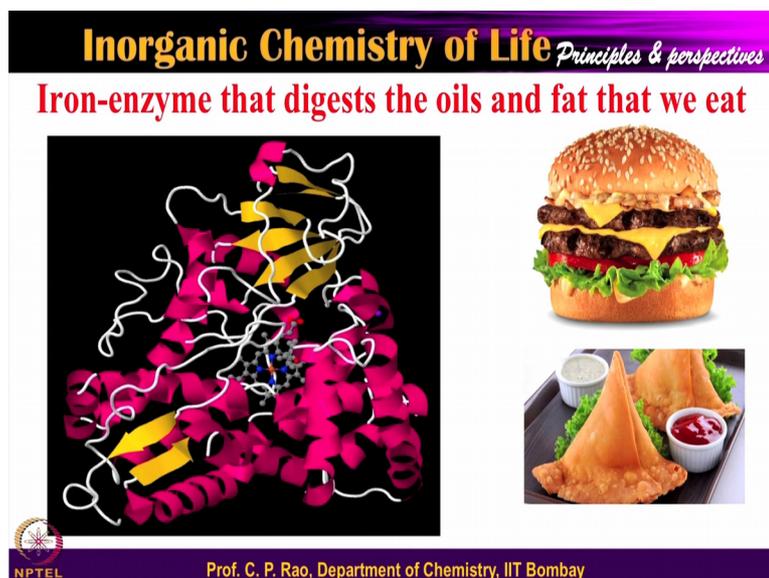
stage. So, you have a protein surrounding and you have an ion zinc ion, I am sorry is the zinc ion not the ion, it is the zinc ion. So, it is a zinc containing peptidase. So, its name is zinc containing carboxy peptidase. So, therefore, this is capable of hydrolyzing the proteins that we eat, ok. Quite selectively all those details I will explain you much later stage, not now much later stage, ok.

So, therefore, the proteins that we eat are not the proteins that we have in body the protein that we eat are hydrolyzed convert into amino acids and these amino acids are rebuilt into a protein and so that is what happens. Rebuilding mechanism I will explain you later. This particular slide I wanted you to appreciate there is a zinc center which is involved in the hydrolysis or breakup of this particular protein material that we eat.

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Inorganic Chemistry of Life *Principles & perspectives*

Iron-enzyme that digests the oils and fat that we eat



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Let us look at one another example, ok. We not only eat you know the protein stuff we are very fond of eating a lot of oily stuff fatty stuff too. So, you can see those things are over here I say this is; obviously, the kind of a to our liking so, but this carries a lot of fat this carries a lot of oil. So, this oil and the fats that we take needs to be digested as well and this again digested in our body and there enzymes again you can see the ribbon like structures and this structures of these kind and all these things is a kind of protein inside you can see this black ball like structures in the blue centres and the red one.

So, this black blue and red one is the heem centre, where the red one being the being the ion center. So, these kind of an enzymes are known as cytochromes. So, this is a

cytochrome like enzyme. So, in the cytochrome like enzyme you have a heem which is embedded inside the protein. If you call this as a core in the core this iron is sitting in the form of a ion heem. So, is a heem containing enzyme. So, this particular centre is responsible for the digesting this oil stuff. How does it do? We will see the details later, but it will do something called oxidation or hydroxylation.

So, the oil stuff fats will be hydroxylated by this enzyme and thereby this oil and fats of being digested in this. So, at the moment what you need to know from this particular slide the whole protein and inside you have a core in that core you have a heem in that you have a ion center. So, therefore, this ion center is not just sitting ideal doing lot of function reactivity and that reactivity will convert the oil, in fact, into a soluble one. Once it makes into soluble one it will go into various processes it can be even excreted as well to.

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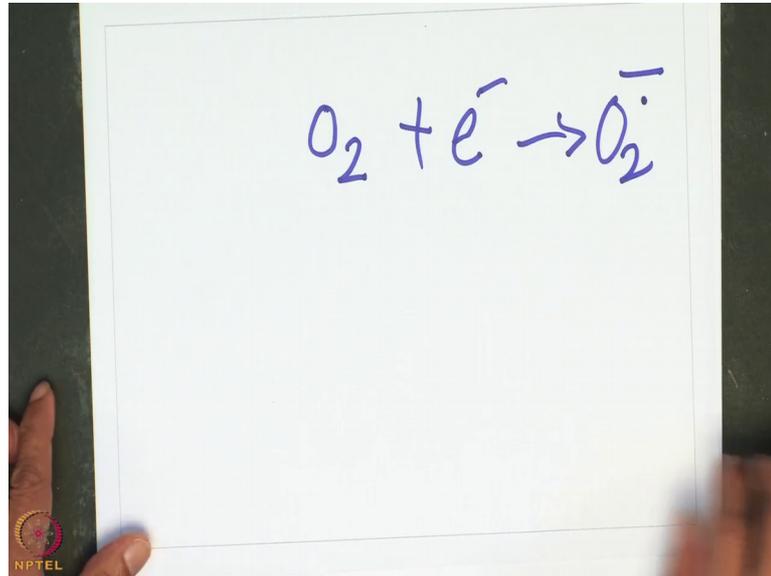
Inorganic Chemistry of Life *Principles & perspectives*
Zn & Cu-enzyme that fights against oxidative stress in our body

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So, let us look at one another example. So, it is not only that so; that means, I have been showing you in the last couple of slides that what I will showing you I have been showing you there is a protein, there is a core and there is a metal centre. So, it doing some kind of a reaction in that. So, now, I have shown one and another enzyme which has got both the zinc and copper and this enzyme does a different kind of a function. What is that different kind of a function? You know the body uses oxygen that means cells use oxygen. So, when the cells use oxygen part of the oxygen is converted into

oxygen based radicals, like you might have heard something like superoxide. So, what is superoxide? When you add one electron to oxygen it becomes oxygen anionic radical O₂ minus dot. So, this is like this.

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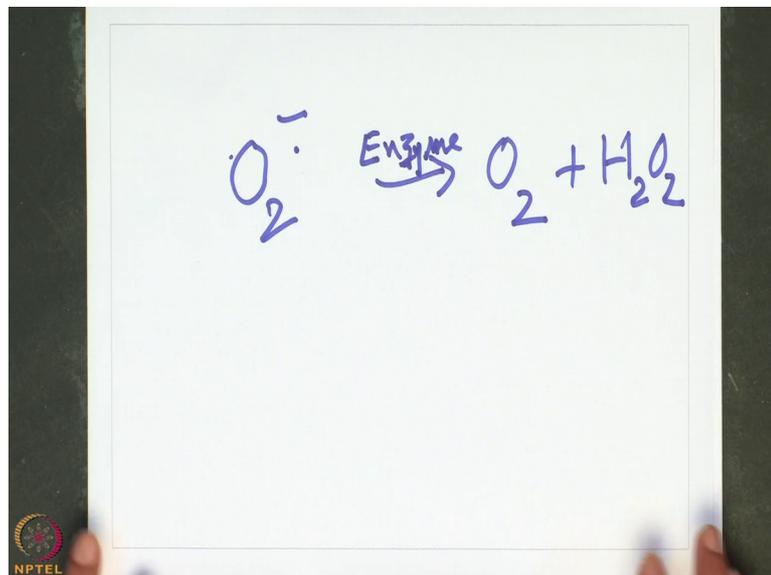
So, you add take oxygen and add an electron to that. So, this becomes O₂ minus dot this is what is the superoxide radical that is formed in this particular thing and this in the cells these are continuously forming an. So, that kind of a things. So, if they are form what is the problem to us? So, if there are formed there is a problem to us because such a kind of a system would basically reactive is a O₂ minus is a radical as you know very well from our simple chemistry radicals react very fast.

So, if they react with the tissue, if they react with the cells the cells will break the tissue will break so that means, all the contents in the in the in the cells and tissue will be open out, so that means, that is oxidative degradation. So, that kind of an oxidative degradation will make transform biological processes and that is where you can see here there are two faces, one with the wrinkled skin, one with a nice smooth skin. So, where you have the radicals dominating process and they starts spoiling the tissue and you take some antioxidants the antioxidants will fill your enzyme and this enzyme will function and work very well and this kind of a pills are there for the containing this enzyme zinc copper superoxide dismutase whole thing.

So, this has got both copper and zinc. You may get a curious thing why both copper and zinc is required you will have to wait for some more hours of teaching at that time I can tell you what exactly the role of this. Right now thing it is not only one metal ion you can have more than one metal ion to, so there is a copper center, there is a zinc center, there is a copper center there is a zinc center also in this, so this particular. So, what do we need to learn from this? There is a metalloenzyme containing zinc and copper this particular thing will convert the radicals into the oxygen.

So, what will it do? So, it will convert this O_2^- into simple O_2 and H_2O_2 kind of thing.

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So, this is creating and this reaction will be taught you bit later with all the balancing etcetera. But right now we need to understand is that what is on the arrow the arrow you have is enzyme.

So, this enzyme converts this particular O_2^- radicals which are generated in to the less harmful H_2O_2 , and non harmful O_2 . How it does etcetera will be learnt later stage, but definitely it will end in this particular course. And let us look at one another example.

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Inorganic Chemistry of Life *Principles & perspectives*
To work restlessly What do you do?

Sources of Vitamin B12

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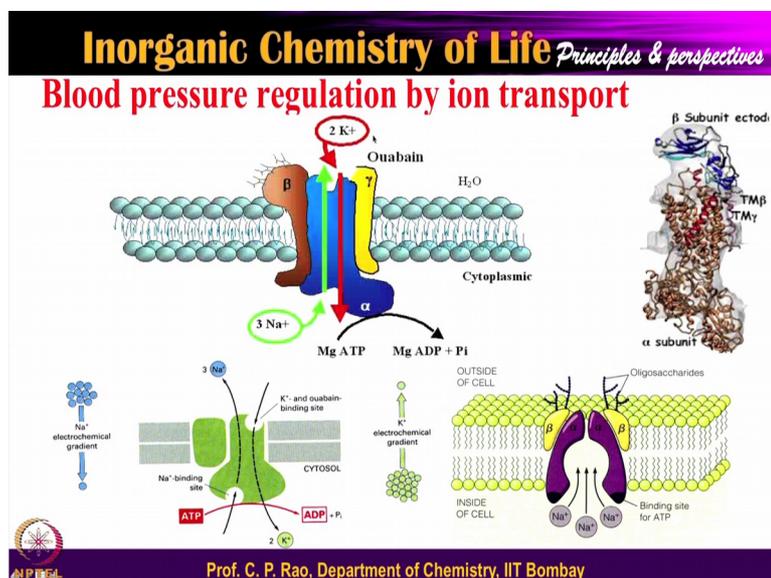
So, this is an example where see sometimes you think that you would like to walk without getting fatigue, ok. So, otherwise you get fatigue, to get the fatigue, therefore, you need to work restlessly. So, you need, you need to be out of fatigue. So, to be out of fatigue means you should be strong enough. So, the you know very well we take vitamin B 12 pills to make ourself strong to regenovate are energies to make yourself fresh so that we can do things much better.

And there are various food stuff are shown over there which have got the vitamin B 12 and the B 12 can be observed by the body and this is supplemented and the corresponding thing comes in the form of the vitamin B 12 which is shown over here structure all the details will be given to you later on. So, vitamin B 12 is a coenzyme this functions along with and large number of enzymes. So, therefore, with working with large number of enzymes with that you have a cobalt ion, this is a cobalt ion. This looks like a porphyrin, but it is not porphyrin it is called corrinring. So, as I said I will explain you the details later this cobalt ion is capable of doing they are providing this process to regenerate your body strength in that.

So, let us look at its not only that, you it can even you know there are some the inorganic ions inorganic ions obviously, and the ionic strength and this ionic strength difference will make the difference in the concentration the concentration difference will come in

the form of a form of a flow or the pressure. So, therefore, such kind of flow or the pressure in blood can be regulated by the ion transport.

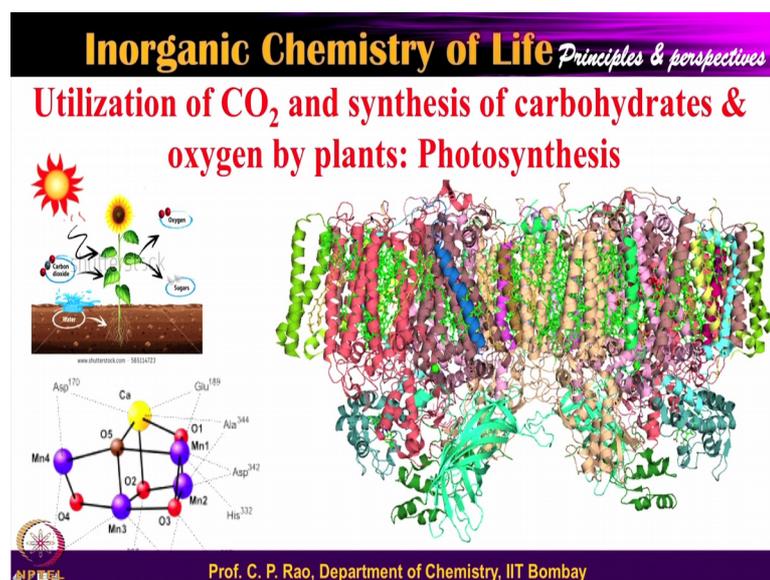
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So, in this particular case, this is a cell membrane and there are some proteins the proteins is a kind of thing and so ions going in and going out mechanisms are there and these are called ATPs pumps. Why they are called ATPs? Because they use the ATP for their transport phenomena and I will be explaining all that, what is ATP, what is not an ATP. All this I will explain you there all that you need to remember now is they require energy to process that and you can see the protein over there the proteins as a kind of a channels.

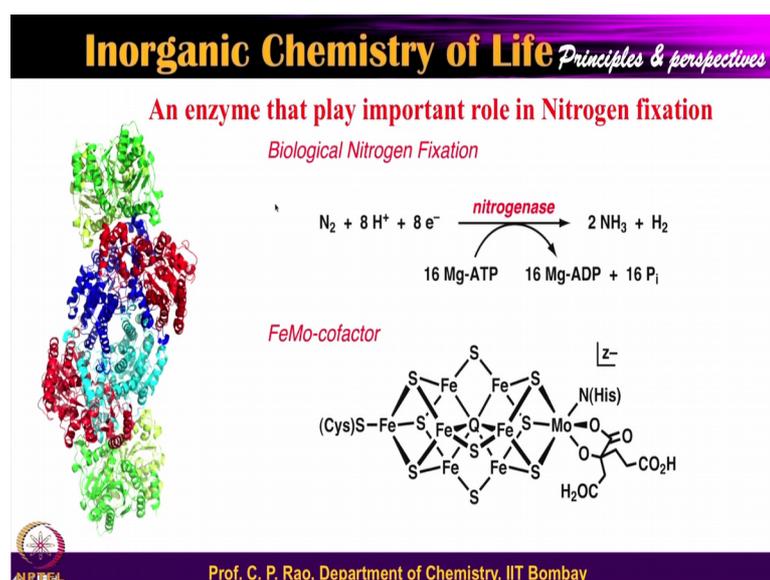
So, these channels are used for ions to take it out and bring in. So, the entire thing is ion balance this ion balance is done by the proteins called ATP just and that will maintain the blood pressure aspect of it to.

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And one and other example, I can tell you even the plants use the sunlight and then you know convert sunlight and carbon dioxide as the inputs and these two are converted to carbohydrates and the oxygen. And this is done by manganese cluster this cluster is present over there. So, therefore, is doing a lot of things. So, it is not only in human even in the plants too.

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So, let us look at one probably the last example in this that where see it is there are some plants like the peanut plant etcetera which takes the nitrogen into the into their plants and

convert into ammonia. So, the nitrogen is converted into ammonia and this is done by and cofactor called ion molybdenum cofactor.

So, this ion molybdenum cofactor is to this particular coupled enzymes which I will explain you convert the nitrogen into ammonia. So, let us try to look at what I have tried to explain you till now is the try to impress you that the large number of enzymes in the body and these enzymes having a metal ion metal ion species or heem or non heem, whatever be the thing is the ions, the metal of making and very important impact in the reactivity therefore, they act like a hero and of course, we are going to study all these in this particular context.

So, for this I think in the, so that will be the kind of a very gross kind of an introduction where at the end I would like to live in your minds that the ions of the inorganic or sitting in the biological system and doing wonders.

Thank you very much.