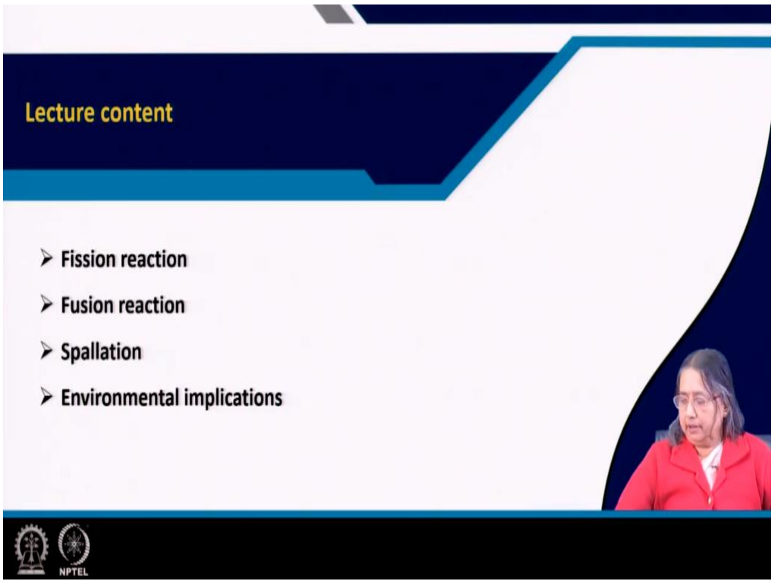
Environmental Chemistry and Microbiology

Dr. Anjali Pal
Dr. Sudha Goel
Department of Civil Engineering
Indian Institute of Technology - Kharagpur

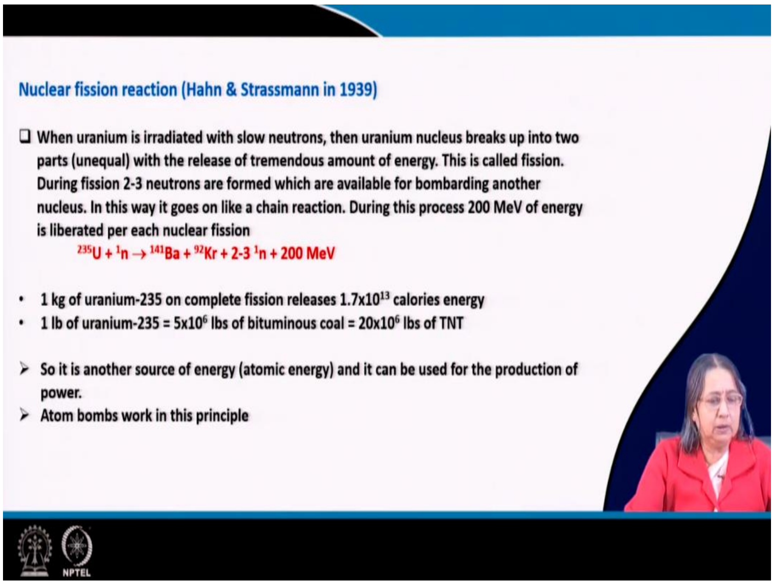
Module - 6
Lecture - 30
Radioactivity (Part-E)

Welcome everyone to our online NPTEL course of Environmental Chemistry and Microbiology. This course will be taught by Professor Sudha Goel and myself, Professor Anjali Pal. We both are from Civil Engineering Department of IIT Kharagpur. We have divided this course into 2 parts. The first part is Environmental Chemistry. It will be covered by me and the second part is Environmental Microbiology which will be taught by Professor Sudha Goel. Now, this is my sixth module and thirtieth lecture. In my earlier lectures in earlier modules, I have discussed about the acids, bases and salts. It was my first module. In the second module, I discussed about the chemical equilibrium. In the third module, I told about the chemical kinetics. In the fourth module, I discussed about the catalysts and catalysis. In the fifth module, I discussed about the chlorine chemistry and nitrogen chemistry. This is my sixth module where I am covering the radioactivity or nuclear chapter. In the previous lectures in this module, I have discussed about the fundamentals of radioactivity, how radioactivity can be measured, what is the background, what is the reason for nuclear stability or nuclear instability. In this lecture, I will cover the following topics: fission reaction, fusion reaction, spallation and environmental implications. I will also talk about the nuclear reactors.

(Refer Slide Time: 02:20)



(Refer Slide Time: 02:41)



First I will tell you about the nuclear fission reactions. In 1939, Hahn and Strassmann irradiated uranium with slow neutrons and observed that uranium nucleus can be broken up. It breaks up actually into 2 unequal parts. Fission means breaking up. With the breaking, they release huge amount of energy. But you have to remember that during fission, 2 to 3 neutrons are also formed which are available for bombarding another nucleus. This is some type of chain reaction. In first step, some nucleus fission is occurring. Then some neutrons are produced. Those neutrons again will break some other nucleus. From the second fission, again some more neutrons are produced. Those neutrons will again break some other nucleus. So, this way, it will be like a chain reaction and 200 MeV of energy is liberated per each nuclear fission. Bombardment of ^{235}U with slow moving neutrons has been shown in (1). It is producing barium and krypton.

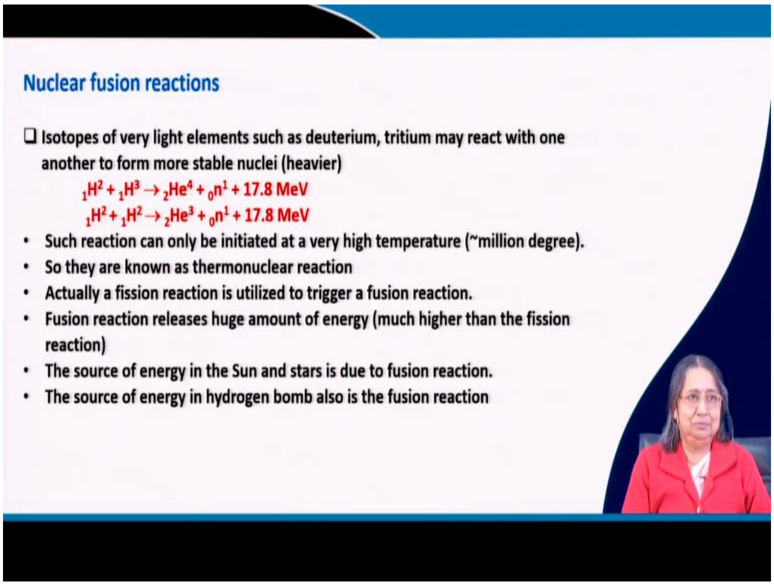
$^{235}U + {}^{1}n \rightarrow {}^{141}Ba + {}^{92}Kr + 2\text{-}3{}^{1}n + 200$ MeV………………………(1)

Mass number of barium is 141 and that of Krypton is 92. So, they are unequal which I already told you. This principle is used to make the atom bomb. During the World War II, this was a project (Manhattan Project) that was taken up in America. They produced this atom bomb and you all know how it has been applied on Japan.

1 kg of uranium 235 on complete fission, releases 1.7×10^{13} calories of energy. You cannot imagine how much it is.

1 pound of uranium 235 is equivalent to 5×10^{6} pounds of bituminous coal which is equivalent to 20×10^{6} pounds of TNT. TNT (trinitrotoluene) is a strong explosive. So, you can imagine that by doing this reaction, how much energy you can get. If we can use it for a good purpose, then it is said that for the next 100 years, we do not have to worry about the electricity. But this is uncontrolled. When it is applied in the atom bombs, then the energy is released. But when we want to use it for good purpose, we have to do in a controlled manner.

(Refer Slide Time: 08:15)



Now, what is nuclear fusion reaction? Fusion, means it is the combination of 2 things. What is the combination? Isotopes of very light elements such as deuterium, tritium may combine together to form more stable nuclei (heavier). Two examples are shown (2) and (3):

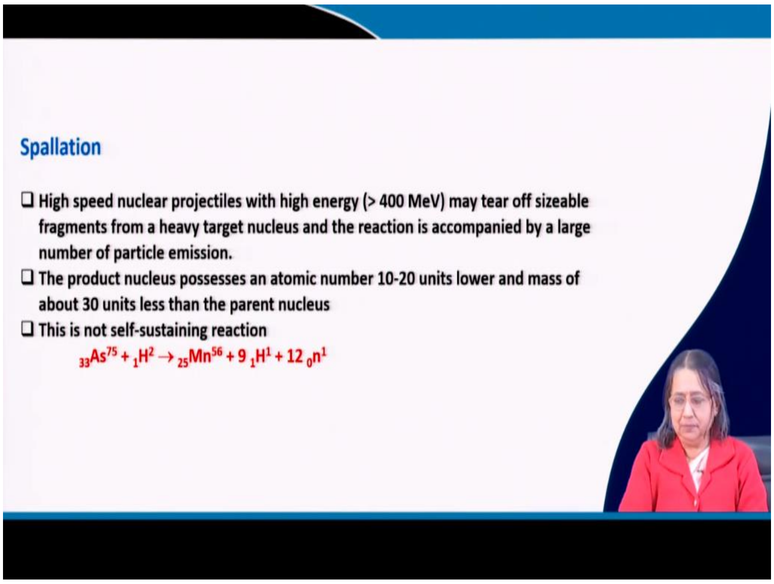
$_1H^2 + {}_1H^3 \rightarrow {}_2He^4 + {}_0n^1 + 17.8$MeV……………...…..(2)

$_1H^2 + {}_1H^2 \rightarrow {}_2He^3 + {}_0n^1 + 17.8$MeV…………………..(3)

In both (2) and (3) isotopes of helium are produced. To initiate this type of reaction very high temperature (million degree) is required. These types of reactions are occurring in sun and stars. So, they are known as thermonuclear reaction. Fusion reaction releases much higher amount of energy compare to the fission reaction.

To do this fusion reaction, we need to have some arrangement so that some fission reaction occurs to trigger this reaction. But how will you do this? This is very difficult task. That is why engineers are trying to do this. The source of energy in hydrogen bomb is also the fusion reaction. If we can prepare hydrogen bomb, then we will get more energy compared to the fission reaction, but it is difficult.

(Refer Slide Time: 12:14)



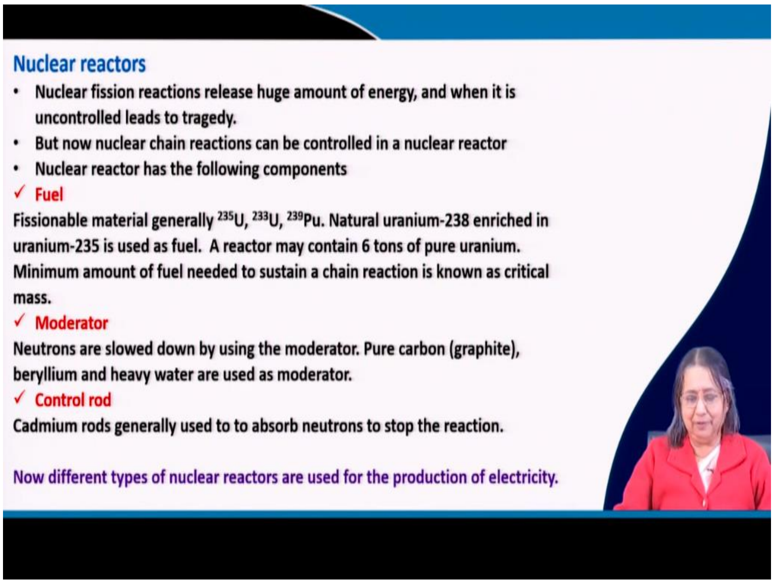
Now, there is another type of reaction which is called spallation. An example is shown in (4):

$_{33}As^{75}+_{1}H^{2}\rightarrow_{25}Mn^{56}+9_{1}H^{2}+12_{0}n^{1}$……………………(4)

This is something different from fission and fusion reaction. High speed nuclear projectiles with high energy (> 400 MeV) may tear off sizeable fragments from a heavy target nucleus and the reaction is accompanied by a large number of particle emission. You see in (4), the product nucleus processes an atomic number 10 to 20 units lower and mass of about 30 units less than the parent nucleus. You are getting some other nuclei along with many particles. This is not self-sustaining reaction not like chain reaction.

So, you have learnt 3 types of reaction: fission reaction, fusion reaction and another is the spallation. Their characteristics are different.

(Refer Slide Time: 14:11)



I told you that fission reactions are done in uncontrolled way so that we cannot utilize the energy for good purpose. Nuclear reactors are designed in such a way so that the fission reaction can be carried out in controlled way and energy produced can be utilised for good purpose. Nuclear reactor has some components which are described as follows:

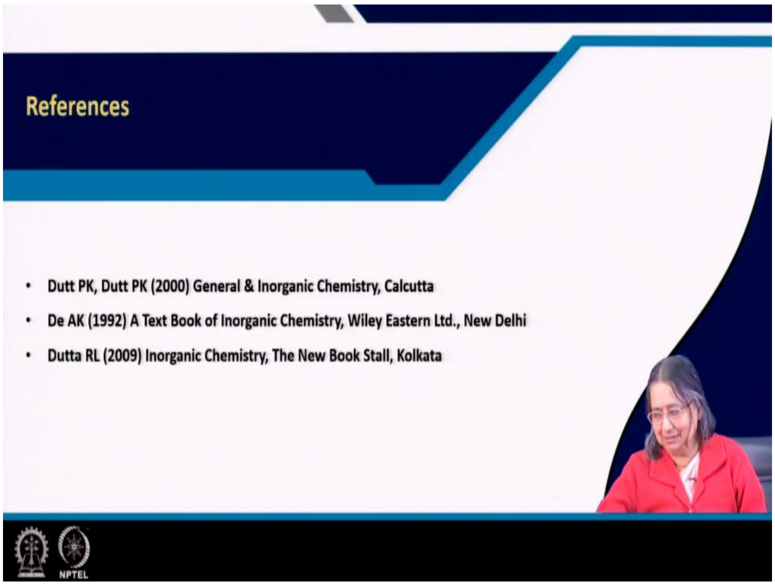
First thing is the fuel. What is fuel? It is not coal or petrol here. Here it is uranium. That is the radioactive element which we want to break. Uranium-235 is used as fuel. In natural Uranium-235 is present in very small amount. 99.3% is Uranium-238 and only 0.7% is Uranium- 235. But we need U^{235} to break. So, how we can do it? We can do it by separating U-235 and U-238. But it is very difficult as it is the isotope of the same material. So, it has same atomic number and other properties. Only difference is mass. That is why its density may be different. But separation is really difficult. It is very costly affair. So, some method is used to enrich the material with U-235. It is not pure U-235, but it is enriched in U-235. A huge reactor can contain 6 tons of pure uranium. But there is something like minimum amount of fuel needed to sustain a chain reaction which is known as critical mass.

The second component is the moderator. You have already seen that fission reaction, slow neutrons are required. Fast neutron will not work there. But when the neutrons are produced, they possess high energy. You have to slow down them. How will you slow down? You can do it by using a moderator. What is moderator? It may be pure carbon, graphite, beryllium and heavy water. Otherwise the chain reaction will not happen.

Now, the next component is control rod. Say for example, you see that it is going beyond control, then you have to stop the reaction or you have to control the reaction. There must be some control rod for that. Cadmium rod is generally used to absorb the neutrons to stop the reaction or to control the reaction. So, these are the major components. There are other things which I have not shown in last slide. There may be something called cladding. It means the material by using which that whole reactor is produced or constructed. It is usually aluminium alloy is used in the reactor. Another thing is required to cool down as huge amount of heat is generated. So, you have to cool it down, otherwise it will burst or it may bring some other effect. Coolant can be water, carbon dioxide, gaseous substance, helium, heavy water. The heat that is captured by this coolant can be used for some other purpose.

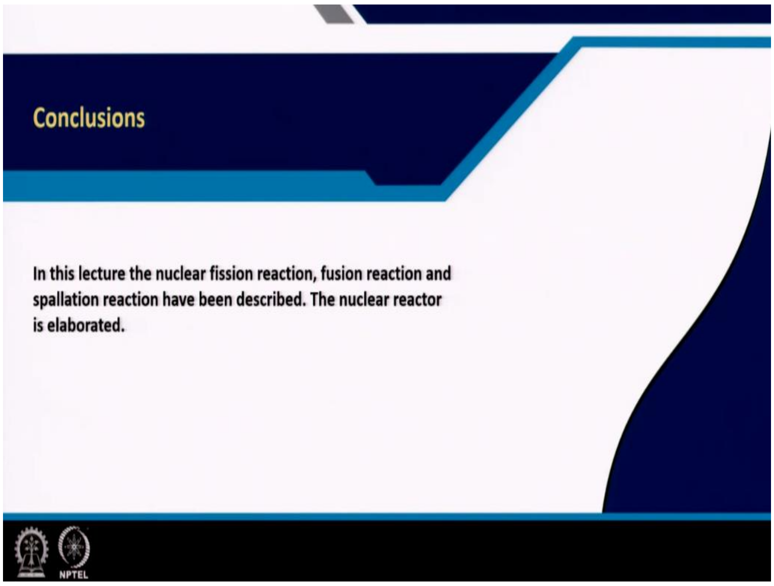
Different types of nuclear reactors are used for production of electricity. You already know that Chernobyl disaster occurred in Russia in 1986. A nuclear reactor burst. Lot of nuclear radioactive materials were spread in different countries by crossing borders. So, those types of things may happen. It is very dangerous. During tsunami also it is told in Japan something happened in the nuclear reactor. If you can make use of nuclear power, it is good. But there are lot of precautions you have to take. Otherwise, it may give lot of disaster and hazards. So, we have to be very careful.

(Refer Slide Time: 22:25)



Now, regarding the reference, I can tell you about 3 same books (mentioned in last slide). It is a very interesting topic and also has many interesting applications. But we have to be very cautious.

(Refer Slide Time: 22:45)



In this lecture, we have discussed about the nuclear fission reaction, nuclear fusion reaction, spallation reaction and nuclear reactor, its main components and about the production of atomic energy there. Thank you very much.