Chemical Reaction Engineering - II
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Module - 1
Lecture - 1
Introduction

Hello. Welcome to the Chemical Reaction Engineering - II course. This is 60 lecture, 30 hour course. I am Ganesh Viswanathan from the Department of Chemical Engineering, Indian Institute of Technology, Bombay. This course will develop on the first level Chemical Reaction Engineering course that you may have taken. In the first level Chemical Reaction Engineering course you would have covered several aspects.

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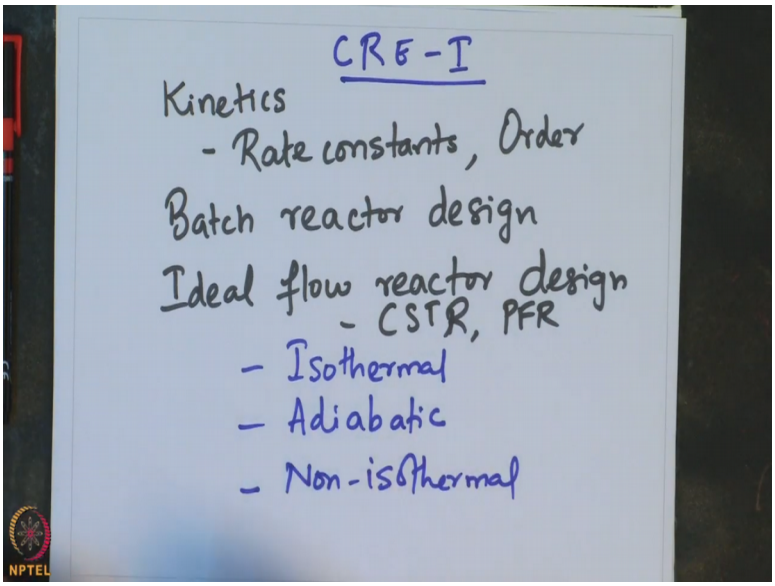

For instance, you would have covered kinetics. Kinetics in which estimation of rate constants and order of the reaction for different cases would have been considered. In addition, you would have looked at the batch reactor design. And you also would have looked at the ideal flow reactor design, particularly that of CSTR and plug flow reactors. In this, you would have specifically looked at isothermal cases, adiabatic condition and non-isothermal condition.

So, these are the essential aspects of a CRE or Chemical Reaction Engineering - I course. So, in this course, in the second level Chemical Reaction Engineering course that we will be covering in this class, would essentially develop further on the material that have been taught or that you have learnt in the first level of Chemical Reaction Engineering or CRE. So, in this particular course we will specifically be looking at several advanced topics such as catalysis;

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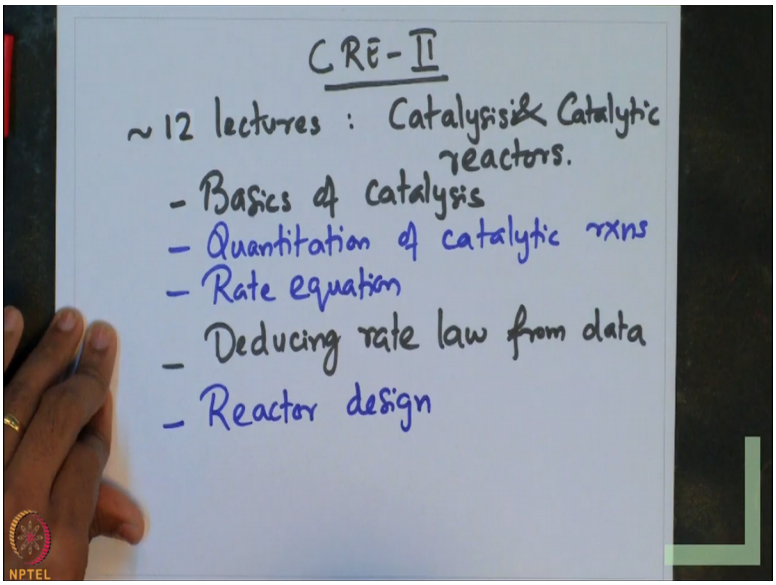

Should be looking at, in this CRE - II course, the Chemical Reaction Engineering second level course, we will be looking at catalysis, we will be looking at catalytic fluid-solid systems, non-catalytic fluid-solid systems and resistance time distribution. And we will spin about 12 lectures including this one, on basics of catalysis and catalytic reactors. In particular, we will be looking at basics of the catalysis itself.

Then we will be looking at how to quantify or quantitation of catalytic reactions. Then we will be looking at formulation of the rate equation. Then we will be looking at deducing rate law for different from data, for many different cases. And then, we will look at the reactor design for several examples, for several different cases. That will be the first major topic of this 60 hour, Chemical Reaction Engineering - II course.

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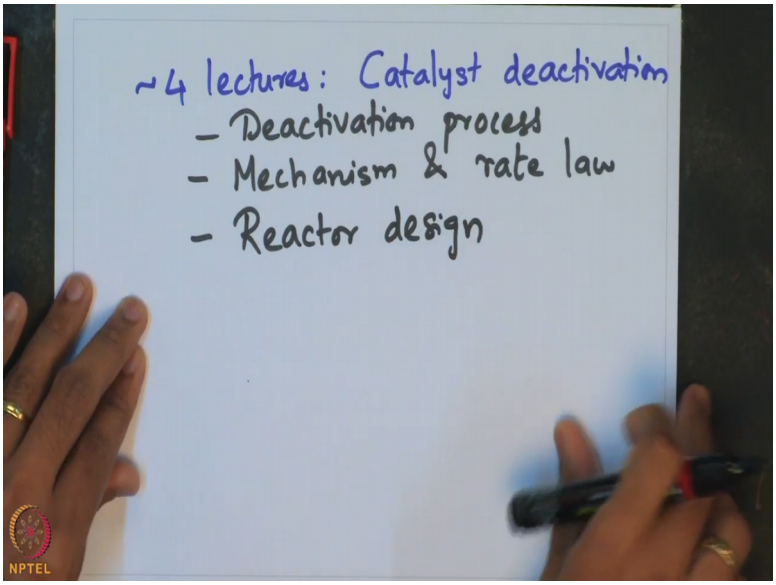

In the second topic which will be approximately 4 lecturers, we will be looking at catalyst deactivation and in particular, we will be looking at the deactivation process itself; what are the different ways of catalyst deactivation. We will be looking at the mechanism and rate law that governs the catalyst deactivation process. And then we will look at how to incorporate these in the appropriate reactor design first few examples. Subsequently, in the third topic, we will be looking at the diffusional effects in catalytic reactors or diffusional effects in catalysts.

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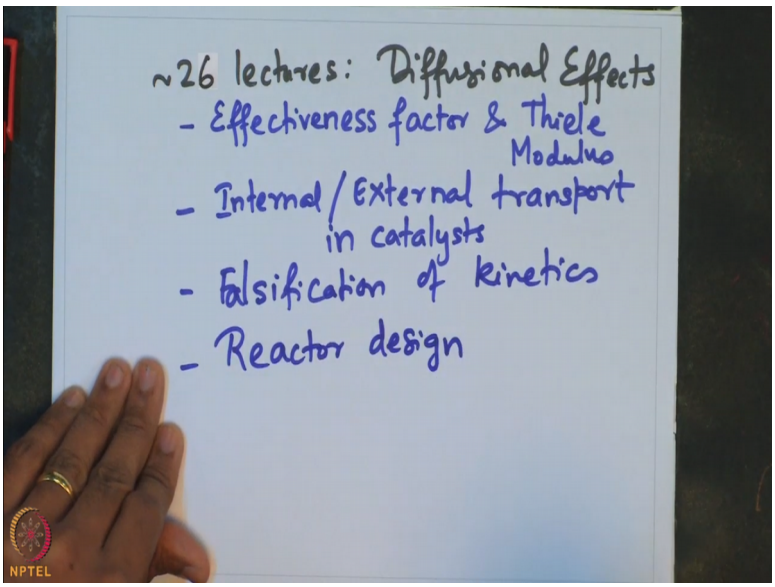

So, we will spin about 26 lectures and this will be the major chunk of the course. We will be looking at the diffusional effects. In particular, we will be looking at a concept called effectiveness and in which we will be using and defining and using this factor called effectiveness factor. And an important module is called thiele modulus. And then, we will extensively look into the internal and external transport in catalysts.

And how it is likely to affect the reaction and so on and so forth. And then, we will look at how the presence of such internal and external transport actually leads to falsification of the observed kinetics; how does it lead to the falsification. And then we will look at how to incorporate these in the actual reactor design.

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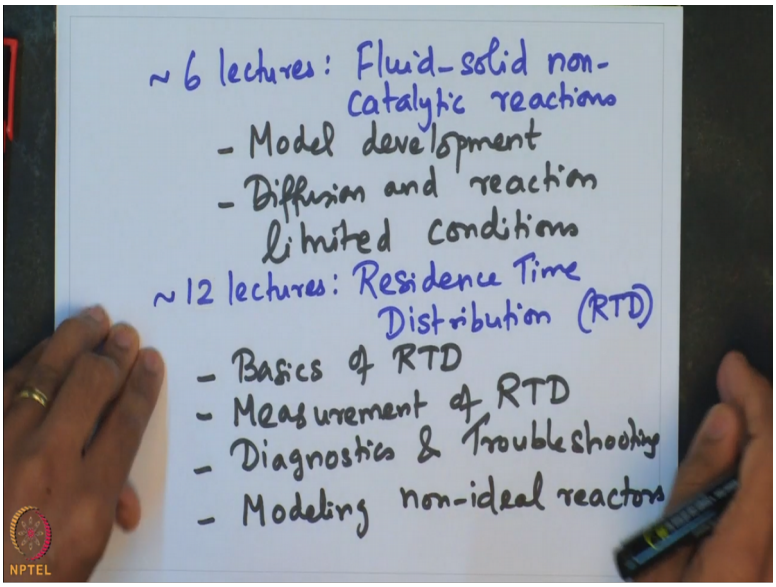

In the fourth topic of the course, we will be spending about 6 lectures looking at the fluid-solid non-catalytic systems, non-catalytic reactions. And in this, particularly we will be looking at model development. And we will be looking at diffusion and reaction limited conditions. In the last topic of the course, 12 lectures, we will be looking at an important topic called the residence time distribution, in short RTD.

In this, we will actually define what is the residence time. We will define what is residence time distribution. We will look at all the basics of RTD. We will look at measurement of RTD; what are the different ways to measure the residence time distribution. We will look at diagnostics and troubleshooting. And lastly, we will look at modelling non-ideal reactors. So, these 5 topics will essentially be covered in great detail and depth in this second level Chemical Reaction Engineering course.

So, let us start with the catalysis, let us start with the first topic of the course. That is, catalysis and catalytic reactors. Catalysis is something which mankind has been using for a very long time, for almost like 2000 years now.

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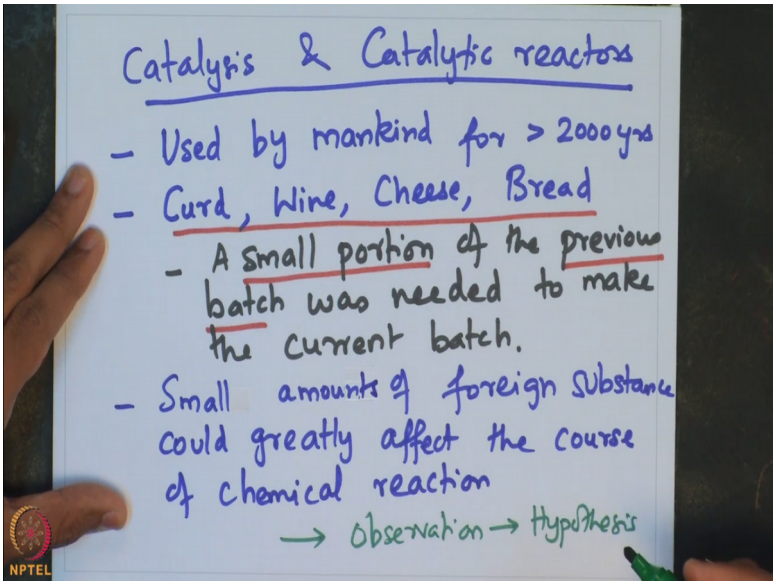

So, it has been catalysis and catalytic reactors. So, it is being used for over 2000 years now, for greater than 2000 years. Specifically, one can look at these sample examples. For example: curd making or wine making or cheese making or bread. All of these involve catalyst, all of these use catalysis. And in fact, it was observed that in all of these cases, it was observed that a small portion of the previous batch, was needed to make the current batch of say wine or cheese or bread or curd.

So, a small portion of the previous batch was needed to make the current batch. That was the observation over, that was the observation made by mankind for so many years now. So, in the late 1800 it was observed that a small amounts of foreign substance could greatly affect the course of chemical reaction. This observation was indeed a profound observation which actually led, observation which led to the hypothesis that small amounts of foreign substance could greatly affect the course of a chemical reaction.

So, it is this observation leading to the hypothesis, has actually led to the birth of catalysis and design of catalytic reactors. It has led to the birth of catalysis and design of the catalytic reactors. Subsequently, it was Ostwald who actually made a more clearer definition of what the catalyst is.

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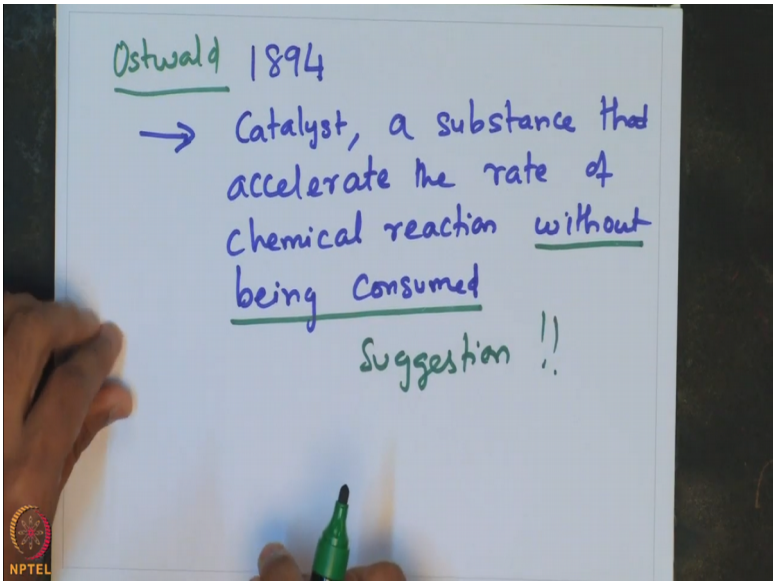

Ostwald in 1894, he suggested that this process which was termed as catalytic actually was a situation where the catalyst, a substance that accelerate the rate of chemical reactions without being consumed. So, Ostwald in 1894 made this definition for catalyst. It is a substance that accelerates the rate of chemical reaction without being consumed. Of importance is this suggestion that without being consumed; it means that when a catalyst is given to the reaction, after the reaction is completed the catalyst actually is preserved as is, or it is not consumed.

That is what was the suggestion that was actually made by Ostwald. So, subsequently, there have been lot of work that has happened on characterising catalyst and also the catalysis process itself, in which the substance called catalyst is actually involved.

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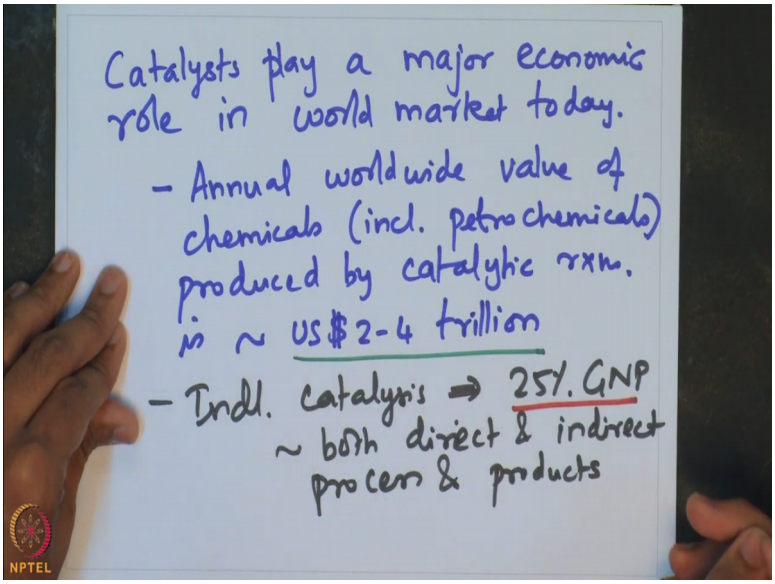

Catalysts play a major economic role in world market today. For instance, the annual worldwide value of chemicals, which actually includes petrochemicals produced by catalytic reactions is valued at approximately US dollars 2 to 4 trillion. It is a staggering number. The total value of chemicals including the petrochemicals produced by catalytic reaction is actually valued at about 2 to 4 trillion dollars. It is actually a substantial and staggering number.

And in fact, the industrial catalysis actually accounts for 25% of the gross national product for several developed countries. In fact, it includes all the directly and indirectly, direct and indirect process and products involving catalysis. That actually contributes to 25% of the gross national product of the developed countries. So, it is a staggering number and you can clearly see from these numbers that the catalysis or the use of catalysts actually plays an important role in the world market today. And it actually means a lot of money. So, the catalysts are used in variety of industries.

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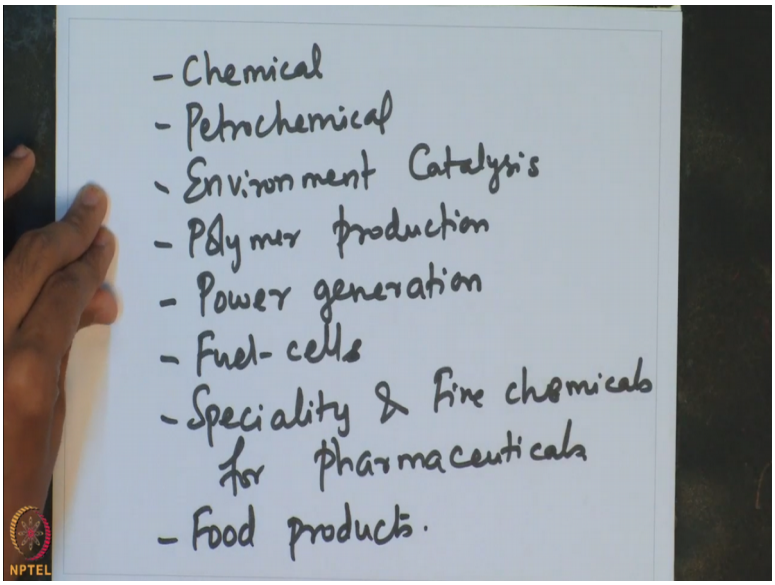

It is actually used in chemical industries, it is used in petrochemical industries, it has strong implication in environmental catalysis for taking care of pollution and etcetera. It is involved extensively with polymer production, variety of polymer production and power generation. Is involved in fuel-cells, speciality and fine chemicals, for pharmaceuticals, for pharma applications and so on and so forth. It is also involved in food products.

So, the catalysis process has wide range implications in variety of industries starting from chemical, petrochemical, catalysis, power generation, fuel-cells, so on and so forth. So,

understanding the process of catalysis and how to use these processes, how to use the understanding in a good reactor design, can actually have, go a long way and actually is very useful in all these Industries that we, I have just listed down. Now, let us look at a specific case of what is the situation in the Indian market.

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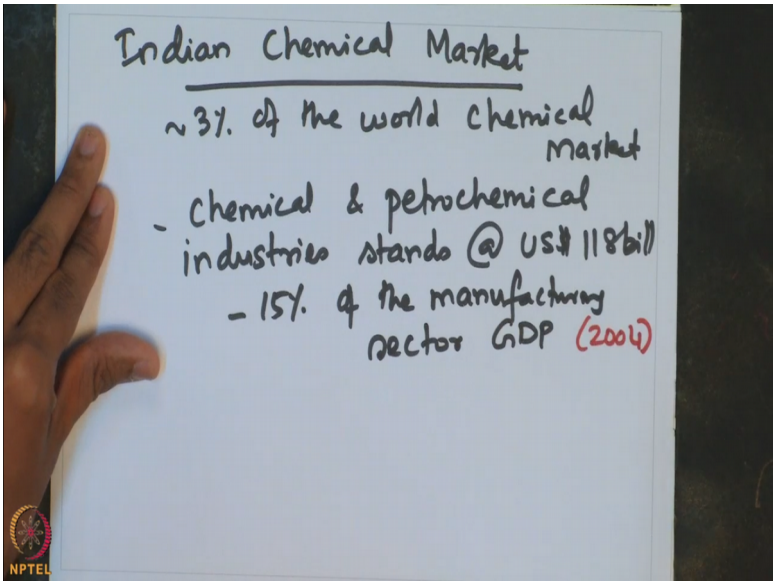

So, in the Indian chemical market as of 2014, approximately 3%, it actually corresponds to approximately 3% of the world chemical market. And in fact, the Indian petro and chemical, chemical and petrochemical industry which extensively use catalyst and have the reactors that are, that use the catalytic process; it actually stands at US dollars 118 billion, which actually is a huge market and it actually corresponds to 15% of the manufacturing sector GDP.

This information is slightly outdated; it is about 2004. I am pretty sure that the information is updated. Now, there are 15% of the manufacturing sector GDP actually comes from the chemical and petrochemical industry's contribution which significantly use the catalysis and the catalytic process. There are several reactors in these chemical and petrochemical reactors petrochemical industries which actually use catalysts.

And it uses the process of catalysis for conversion of some reactants into products which go in to the market and eventually it is converted into you know, products that are useful for normal day-to-day processes.

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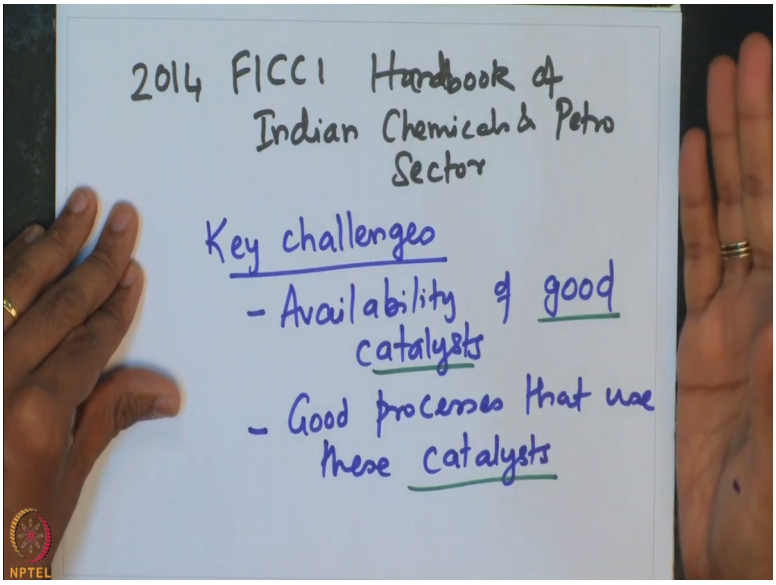

So, the 2014 FICCI handbook released by the government; FICCI Handbook on Indian Chemicals and Petro Sector suggests that, observes that, the key challenges that is faced by these industries are the availability of good catalysts and good processes that use these catalysts. So, it is indeed a challenging problem and it is indeed needed for the Indian context as well. The Indian Chemicals and Petrochemicals sectors depend greatly on catalysts and the catalytic process.

And as of 2014, that these 2, availability of good catalysts and availability of good processes that use these catalysts are still the challenge and is in demand. And what we are going to see in this course is extensive characterisation of catalytic systems and catalytic reactor design and clearly these would have a strong implication on its potential use in terms of designing good processes and arriving at good catalysts for achieving good selectivity and yield for a given product of desire.

So, with this broad overview of the impact of catalyst and the catalysis process on the world and the Indian scenario, let us delve a little bit more into the history of the catalyst. The first process which actually is known or at least it is been recorded as a catalytic process, it is the production of diethyl ether.

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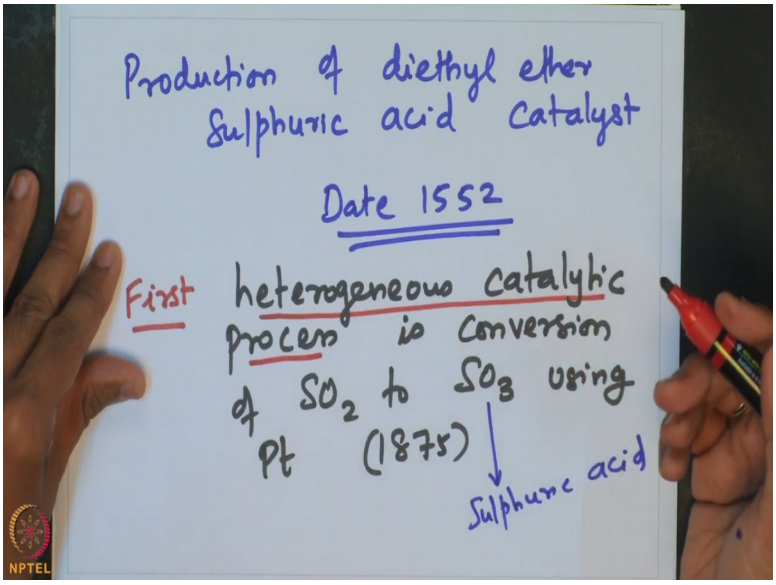

One of the older documented catalytic process is the production of diethyl ether for which sulphuric acid was used as a catalyst. And there are documented records which basically date 1552 which suggests that such a catalytic process was actually in place and that time. It is not known as to when this catalytic process of production of diethyl ether using sulphuric acid was actually started, but it is recorded that it was in use at that time.

The first heterogeneous catalytic process is the conversion of S O 2 to S O 3 using platinum as a catalyst. And in fact, this dates back to 1875. That was the first time this process was actually found. And this process is indeed very useful because this is, S O 3 is what is used in actually manufacture of sulphuric acid. So, this process of heterogeneous catalytic process which we will see in great detail in this course.

We will define in the next lecture what is heterogeneous catalytic process. And how to characterise this, how to quantify each of these, and what are the different steps in understanding the heterogeneous catalysis process. And how to incorporate this understanding and the insights that we gain from the catalysis or characterisation of the heterogeneous catalysis in the reactor design, in the actual reactor design. Thank you.