Mass Transfer Operations – I
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Diffusion Mass Transfer
Lecture – 01
Introduction and Overview of Mass Transfer Operation

Welcome, to the first lecture on Mass Transfer Operation – I. In this lecture, I will try to introduce you on the principle of mass transfer.

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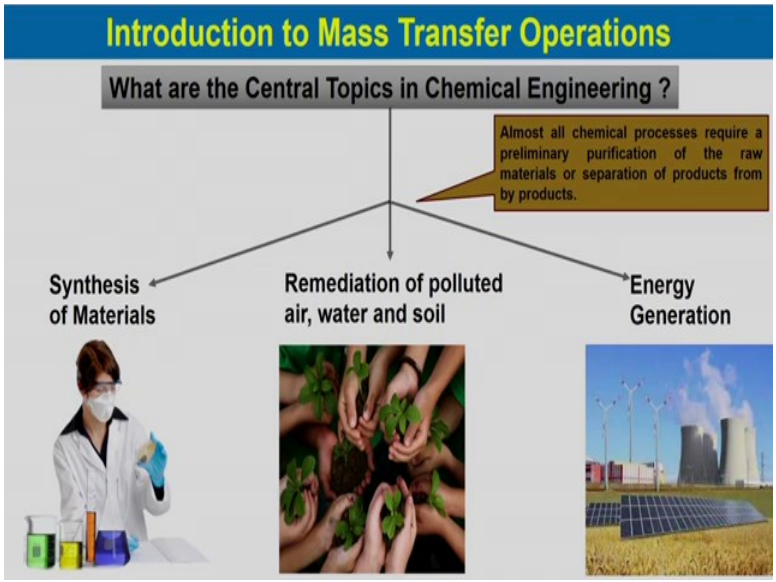

What are the central topic in chemical engineering? There are three major topic. One is the synthesis of materials. For any raw materials we need to process them and to make finished products for our daily use or for different uses. That is one of the important part of the topic of chemical engineering.

The second part is the remediation of polluted air, water and soil. The industrial revolution and day to day activities lead to the pollutions of the environment, which is exist in three forms air, water and soil all these are get polluted and we need to have remediations of these three forms of the materials exist on the earth.

The third thing is that to operate any process or to survive we need energy. So, energy generation is another part of the chemical engineering topic. So, almost all chemical

processes require a preliminary purifications of the raw materials or separations of products from byproducts.

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Separations of chemical mixtures into their constituents has been practiced for a long time. Like if you considered the extract metals from ores, we need perfumes from flowers and dyes from plants. We use all these for different purposes. Like we use our, you know common salt we use for our uses one of them is the sodium chloride which is which we use can we can generate them by evaporation of the sea water.

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The other examples is the distilled liquor. So, to produce liquor these are the common examples where separation process involved.

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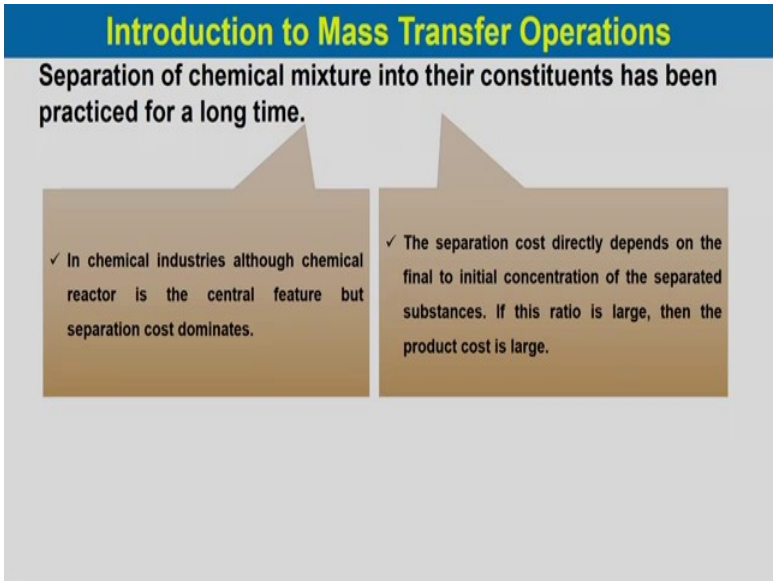

In chemical industries we have chemical reactors and then separations. The chemical reactors is the central features, but in terms of the cost the separation cost dominates over the chemical reactors. The separations cost directly depends on the final to the initial concentration of separated substances. If this ratio is large then the product cost is large. For examples, if we take sulfuric acids; sulfuric acid we can get in a very cheaper materials and or the cost is much less compared to other materials like why this is so because the sulfur which is exist in the nature in much purer form than the others. So, we can produce sulfuric acid in a much cheaper cost.

If we consider the pure uranium, we want pure uranium then the cost for the uranium is much higher because in the nature it is found in much less quantity or in low concentration. So, to purify and produce a pure products it involves huge separation cost. So, its cost is much higher. So, that is why, the final to the initial concentration of the separated substance determines the cost of the product.

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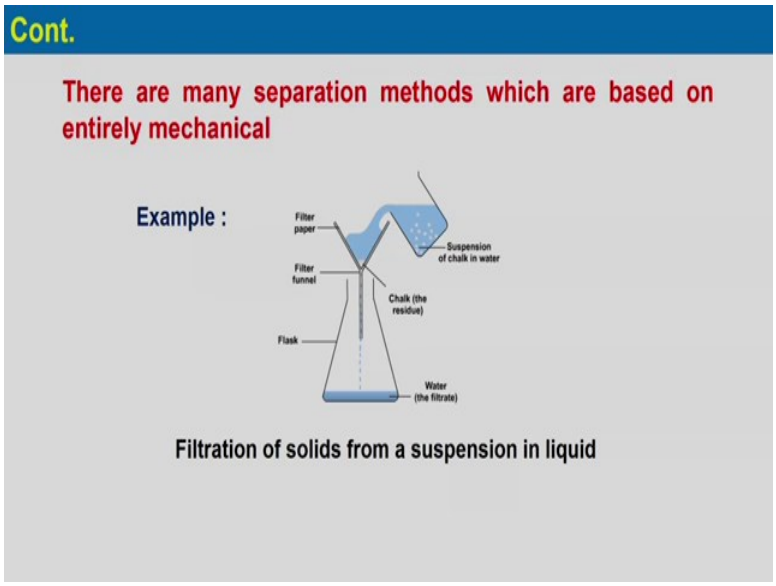

There are many separation methods which are based on entirely mechanical. Chemical engineers are more concerned on the productions of the materials in an economical way, like it is different than the chemistry look into a material. One of example is that we want it to separate the hydro carbon mixtures. The chemist will use the chromatography technique to separate them, but the cost will be much higher. Whereas, the chemical engineers will look into separate this materials in a cheaper cost in a conventional distillation process.

There are many separation methods which are based on entirely mechanical; like if we consider filtration of solids from a suspension in liquid, like you take a suspension of chalk in water and then you filter it and you will separate water and the chalk particles. So, this is entirely the physical separations.

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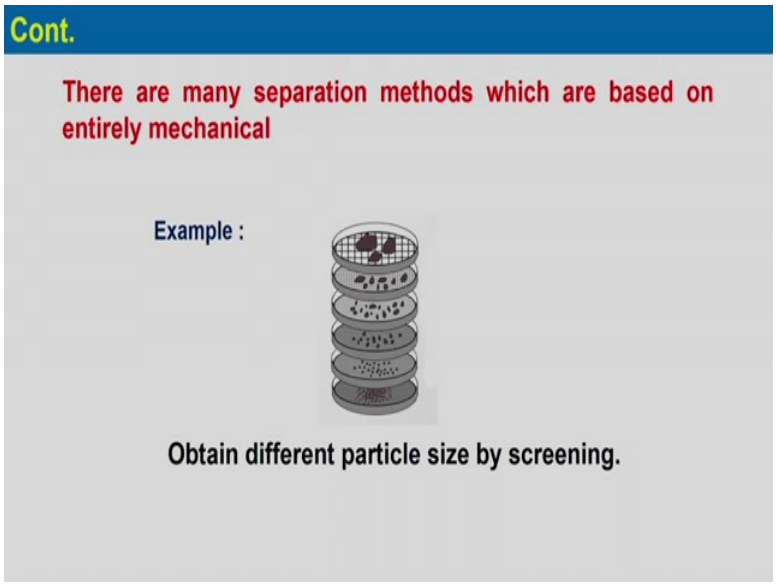

Another examples are the screening; separation of different particle grids or different particle sizes by the screening. You have seen in your under graduate course in a mechanical operational lab, we use different kind of you know physical separation units like jaw crusher, roll crusher and so on these makes the particle the raw materials of large chunks of raw materials to produce a smaller sized particles and then you can screen them by different screen and get the different particle sizes. These are entirely physical separation methods.

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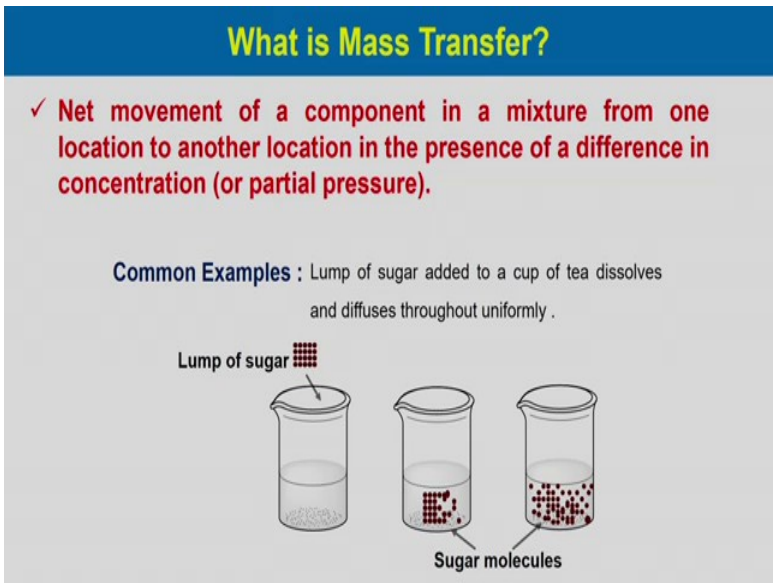

Then what is mass transfer? The mass transfer is the net movement of a component in a mixture from one location to the, another location in presence of a difference in concentration or partial pressure. So, when there is a driving force then mass transfer will occur. The driving force over here is the concentration or partial pressure difference. Let us consider one common example of mass transfer. Suppose, if you have taken a lump of sugar added to a cup of tea which dissolves and then diffuses throughout the tea cup uniformly.

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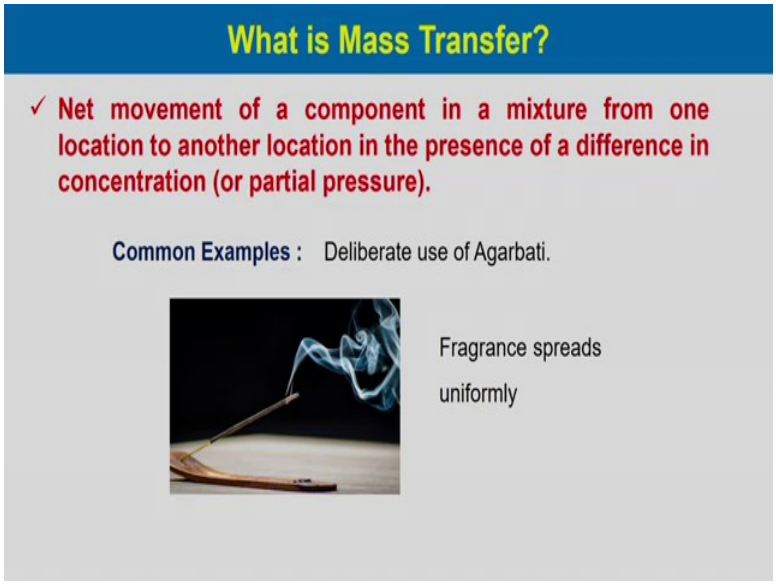

So, another examples are the deliberate use of agarbati. So, the fragrance generally spreads uniformly when we put agarbati at home.

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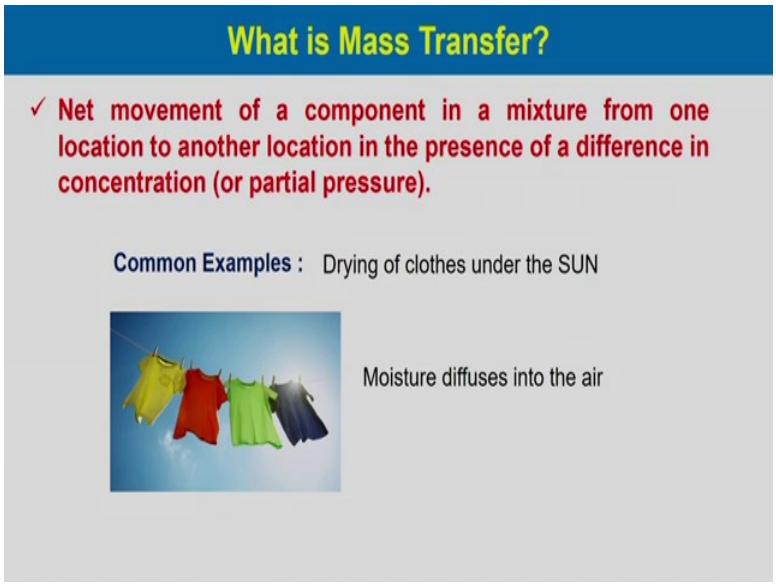

The other examples is drying of clothes under the sun. Here the drying occurs because the moisture diffuses into the air. So, the diffusion or the so, the mass transfer is basically occurs with a particular driving force. Like if we want to consider a movement of solid through the conveyer belts or movement of liquid through a pipe is not the mass transfer operations because it is not based on the concentration or partial pressure driving force.

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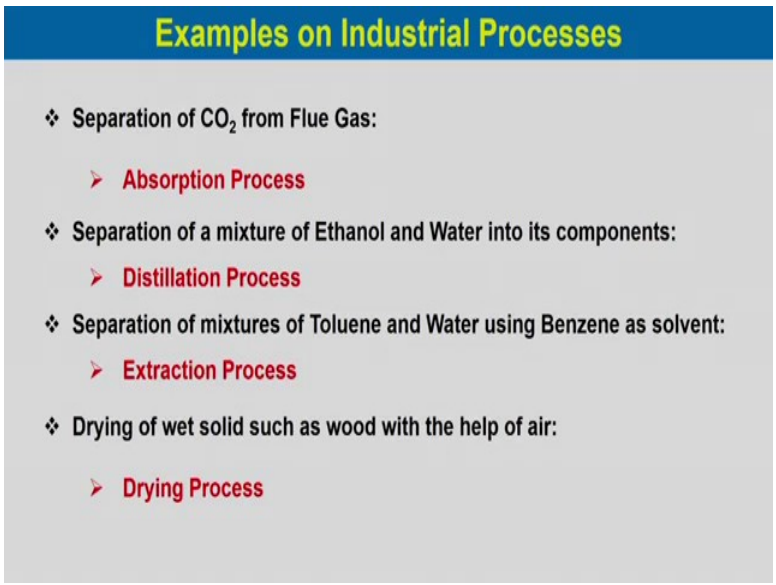

The common examples on industrial processes are separation of carbon dioxide from flue gas. One of such examples is the absorption process where we absorb the particular

gas selectively into the solvent using a solvent. These are one of the, this is one of the of the examples for common industrial process. The another example is the separation of mixture of ethanol and water into its components. The process by which we separate them is the distillation process.

The other example is the separation of toluene-water using benzene as solvent and the process which we use is known as the extraction process. Drying of wet solids such as wood with the help of air and the process is known as the drying process. So, the chemical separation methods which includes absorption, distillation, liquid-liquid extraction, drying, leaching and some of the new newer processes like adsorption and membrane separations.

Knowing the principle of operations chemical engineers can successfully develop design and operate industrial processes. How to classify mass transfer operation? As we know there are three states of matter the gas, liquid and solids. So, the combination of these three states can form three different phases of possibilities of phases of contacts.

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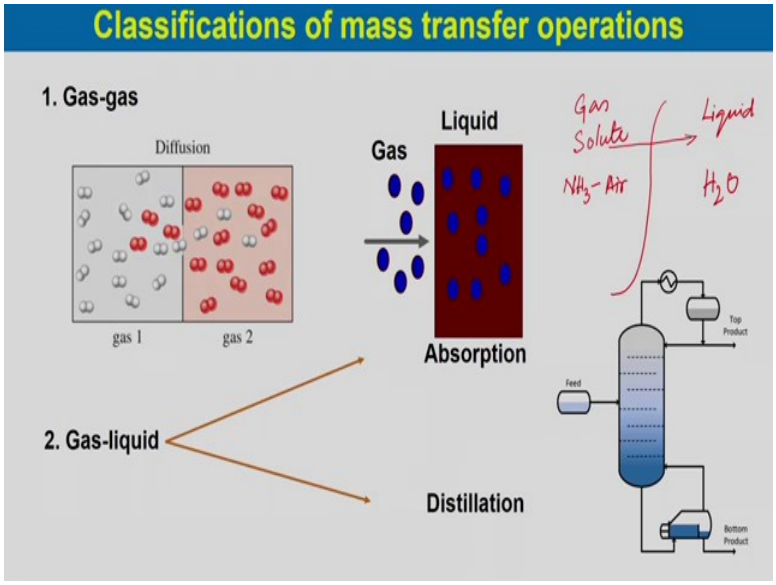

One of them is the gas-gas systems, like if you have two different gas and if you just keep them in two container and allow them to mix they will uniformly mix by the process of diffusion. But, in this case for gas-gas system since most of the gases are miscible so, the phases or the interface getting between the two gas phase is very difficult. So, gas-gas systems is practically non exist, or it is practically non realized.

The second system is the gas liquid systems. Here absorption is one of such examples of gas liquid systems. Suppose consider a solute changing hands between gas and liquids. Solute and changing from gas phase to the liquid phase. So, basically consider a two mixture of ammonia and air and we have water in the liquid phase. Here, ammonia will preferentially dissolved in water and form ammonium hydroxide preferentially and assuming that air does not dissolve in liquid. So, in this case there is a interface between gas and liquid phase and one component of the gas phase preferentially dissolve in the liquid phase, form a solution of that is known as the absorption process.

The second one is the distillation process. It is an equilibrium stage operation in each stage a vapor. So, we have a reboiler where we heat the liquid and it forms a vapor phase and liquid is fed from the top as a reflux and it comes down and there is intimate contact between gas and liquids. So, when there is difference in their boiling points among the mixture of the components then we can create two phases one vapor phase and another liquid phase. Vapor phase will be mostly on the lighter component and the liquid phase will be on the heavier components.

So, in this way we can separate two different components or the multiple components and we this process is known as the distillation. Like we one of such examples is the separation of petroleum crude into gasoline, kerosene, fuel well and lubricating stock.

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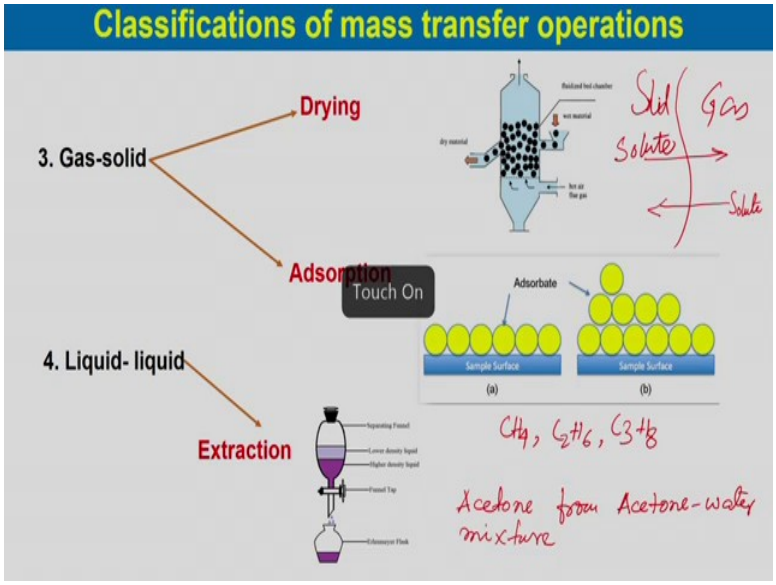

The third process is gas solid systems which is drying, and as already said suppose in this case also the mass transfer happens from the solid phase to the gas phase. So, similarly consider an interface between the solid and the gas so, and absorb moistures will diffuse the solid will diffuse to the gas phase. So, this is known as the drying process like drying of wood or laundry by exposure to air are the examples of the drying.

The other process is adsorptions. When the mass transfer happens from the gas phase to the solid phase, so, the solute which will transfer from gas to the solid, then the process is known as solute transfer from gas phase to the solid phase the process is known as adsorption. Considered a mixture of methane, ethane and propane; CH_4, C_2H_6 and C_3H_8, methane, ethane and propane and if you adsorb in into a solid materials there will be the relative adsorptions of this three components will vary and we will get a separations of the components.

The fourth systems is the liquid-liquid systems and which is known as the extraction. So, extraction is the process of separation involving two immiscible phases, here is solution which is called feed is brought into intimate contact with a second insoluble or slightly miscible liquid called the solvent in order to achieve transfer of solute from feed to the solvent. Like separation of acetone from acetone water mixture. Acetone separation of acetone from acetone water mixture is an example of extraction.

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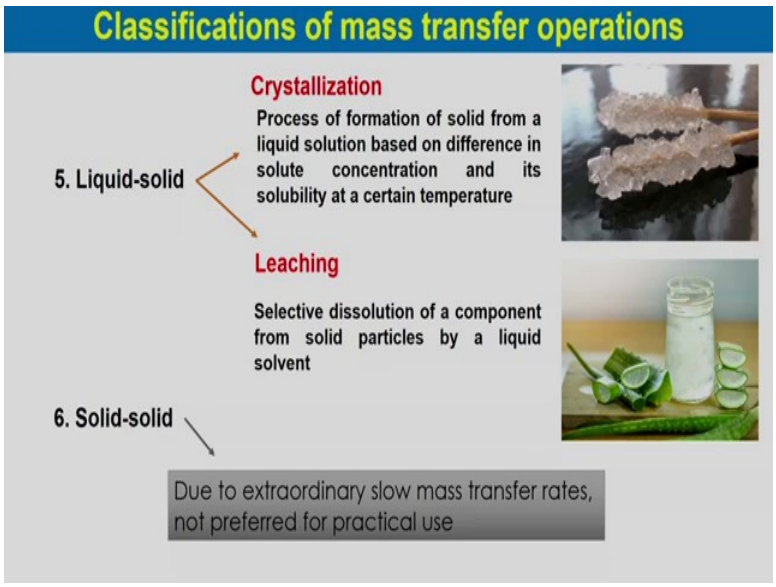

The fifth example is liquid-solid systems. The crystallization is an example of liquid-solid systems. This is the process of formation of solids from a liquid solution based on difference in solute concentration and its solubility at a certain temperature. One of such examples is the formation of the sugar cube as we have seen. So, this is one of the example of crystallization.

The solid-liquid systems also involved leaching, like we extract different medicinal components from plants. So, selective dissolution of a component from a solid particle by a liquid solvent is known as the leaching process and one such example is to formation of some medicinal components from the plants medicinal or extractions of some medicinal components from plants. We also have extractions of different valuable metals from ores that is one of the liquid-solid operations.

The sixth system is the solid-solid systems due to very extra ordinarily slow due to extraordinarily slow mass transfer rates. This process solid-solid process are not preferred for industrial use or practical purpose, because if we look into the mass transfer rate in terms of the diffusion of the components in a solid-solid systems which is very less compared to the mass transfer rate of other five systems we have discussed so far.

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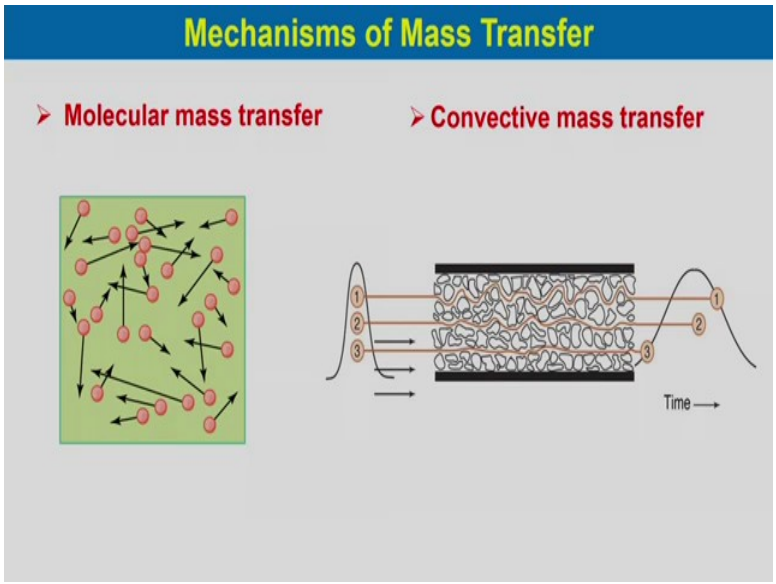

Mass transfer occurs by two basic mechanisms. One is molecular mass transfer. The molecular diffusion by random and spontaneous microscopic movement of individual molecules in a gas, liquid or solid as a result of thermal motion is known as the

molecular mass transfer. The second mechanism is the convective mass transfer. In this case eddy diffusion by random macroscopic fluid motion is the responsible for the convective mass transfer.

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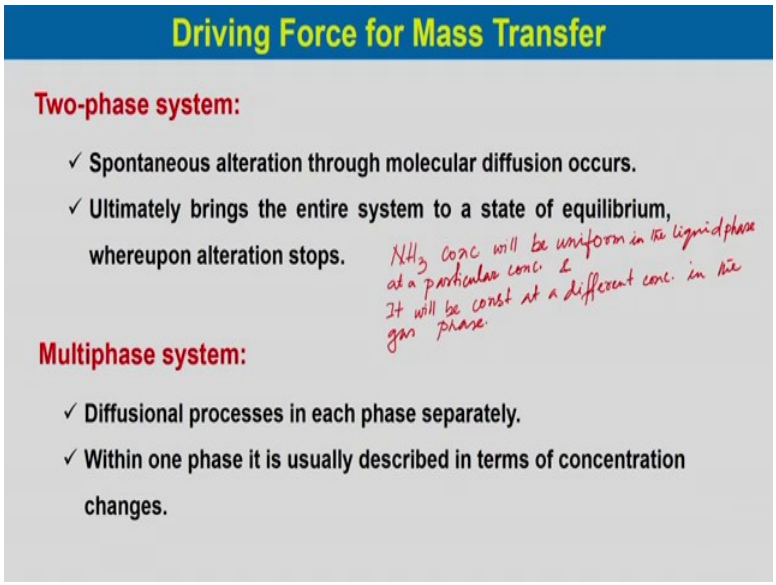

For mass transfer one of the important parameter is the driving force. In a two phase system spontaneous alterations through molecular diffusions occurs. Basically if we take air ammonia mixtures the ammonia diffuses to the liquid and spontaneous alterations of the molecular diffusions occurs and ultimately the systems comes into a state of equilibrium where the alteration stops; that means, at the end we observed that the concentration of any constituents is the same throughout the phases. But, it will not necessarily same in both phases. Thus the ammonia the ammonia concentration will be uniform in the liquid phase at a particular concentration and it will be constant at a different concentration in the gas phase.

So, as we observe the ammonia concentrations although the systems comes into equilibrium, the ammonia concentrations are uniformly distributed in one phase in each phase separately; however, they are not same in both the phases. So, then what is the driving force which makes the mass transfer came into halt? If we look into the chemical potential or the activity if the same reference state is used which is differently dependent upon the concentration in the two phases, we can see that it will be uniform everywhere

throughout the systems at equilibrium and it is this uniformity which brought the distinctive process a halt eventually.

So, the true driving force for diffusion is activity or chemical potential and not the concentration gradients. However, when we consider multi phase systems we customarily deal with diffusion process in each phase separately and within one phase it is usually described in terms of concentration changes. So, whenever the mass transfer involved in one phase we considered concentration is the driving force when there is a multiple phases or more than a two phase systems basically the true driving force for mass transfer is the chemical potential.

So, in the next lecture we will discuss on the diffusion mass transfer and discuss its application.

Thank you.