Mass Transfer Operations I

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Module - 1
Diffusion Mass Transfer
Lecture - 1
Introduction to Mass Transfer

Welcome to the first lecture on mass transfer operations one. In this lecture, I will introduce you to the mass transfer operations, and give you the whole of this course, and the detail course structures will be elaborated.

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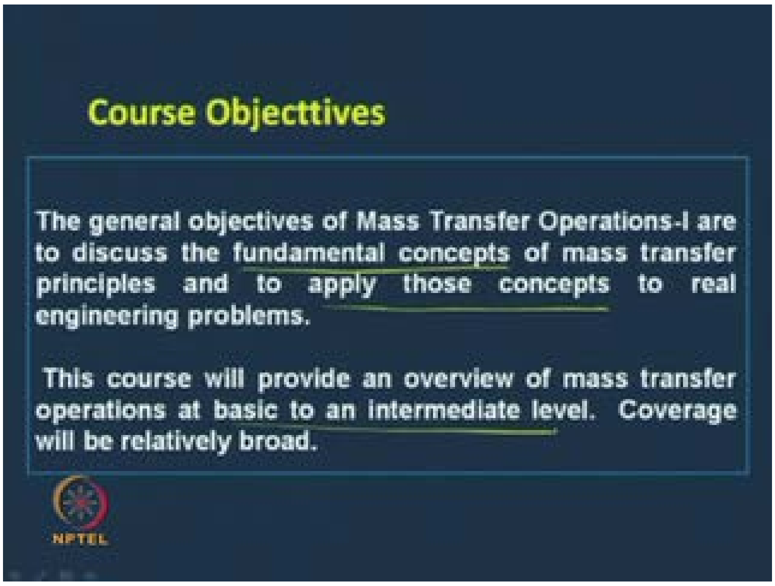

The main objectives of this course is to discuss the fundamental concepts of mass transfer operations and principles, and apply those concepts to real engineering problems. This course will provide an overview of mass transfer operations at basic to an intermediate level, and the coverage will be relatively broad.

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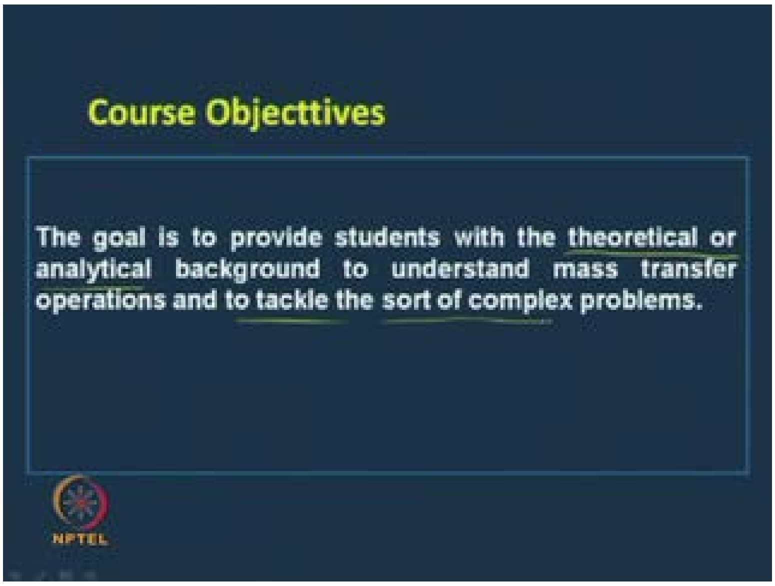

The goal is to provide students with the theoretical or analytical background to understand mass transfer operations, and tackle sort of complex problems.

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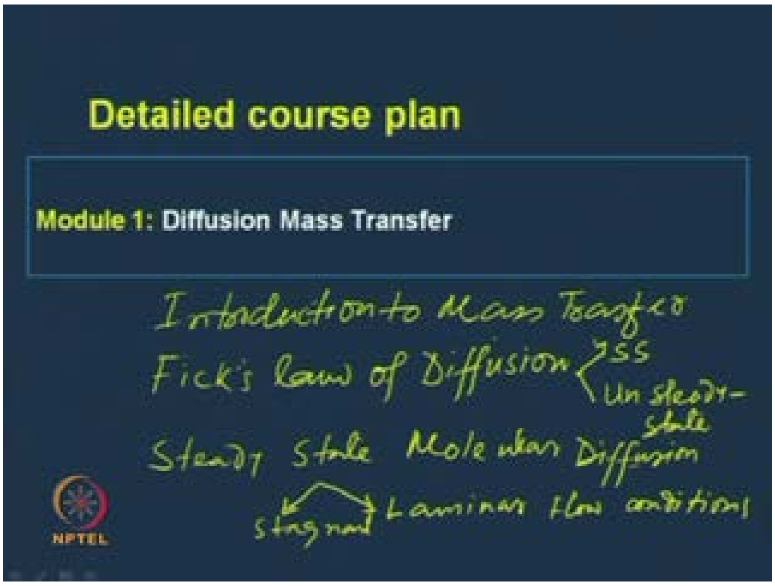

The detail course plan in module 1 will discuss mass transfer operations and diffusion. Here we will discuss the diffusion mass transfer; we will introduce you to the mass transfer operations. So, introduction to mass transfer Fick's law of diffusion both under steady state conditions and unsteady state conditions. Steady state molecular diffusion, this is under stagnant as well as laminar flow conditions.

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Then we will discuss diffusion coefficients, its measurement, and as well as prediction. Then introduction to multi component systems, molecular diffusions in solids, and its application.

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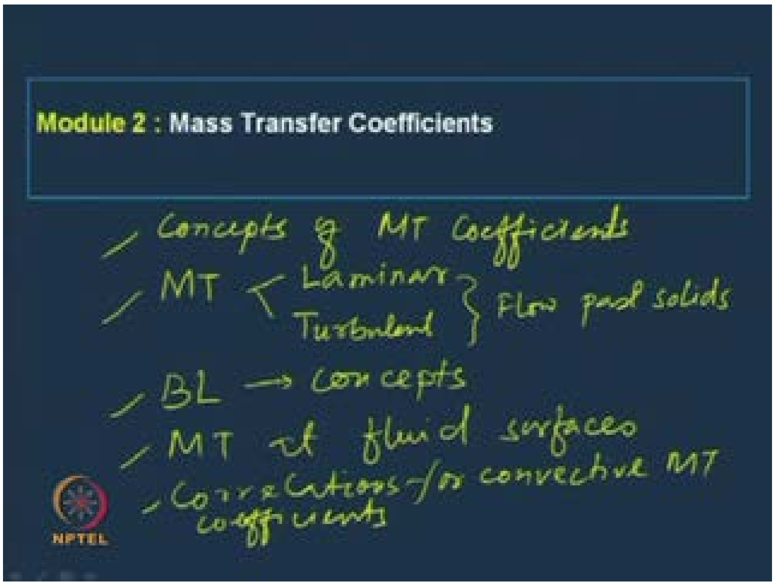

So, in module 2; we will discuss concept of mass transfer coefficients, mass transfer under laminar and turbulent flow past solid, boundary layer concepts, mass transfer at fluid surfaces, correlation for convective mass transfer, correlations for convective mass transfer coefficients.

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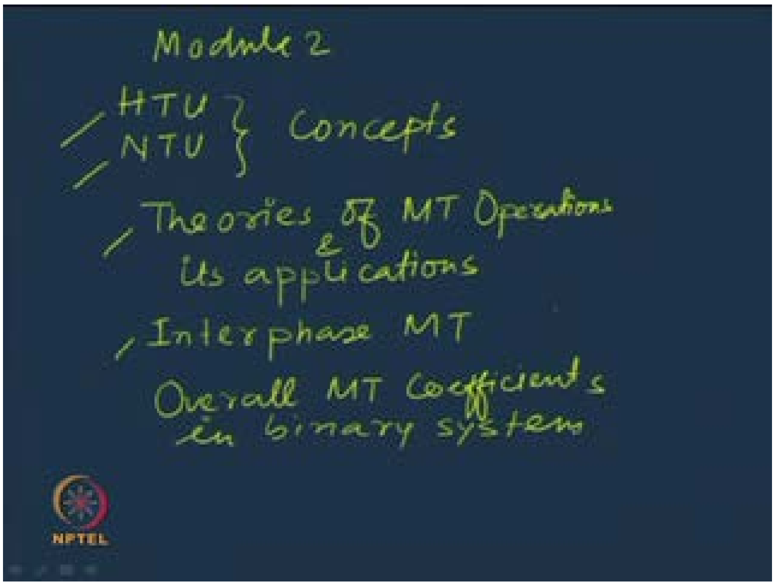

In module 2, we will also discuss height of transfer units HTU, and number of transfer units NTU concepts, theory of mass transfer operations and its applications, interface mass transfer, overall mass transfer coefficient in binary system.

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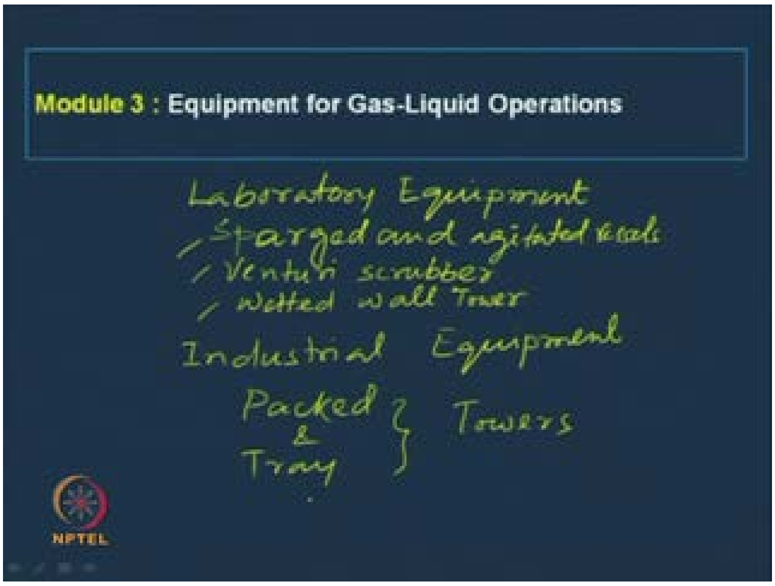

In module 3, which is equipment for gas liquid operations. There are two types of equipment; one is laboratory equipment, laboratory equipment and second one is industrial equipment. In laboratory equipment, we will be discussing sparged and agitated vessels, venturi scrubber, and wetted wall tower. And in industrial equipment, particularly we will discuss packed and tray towers. These laboratory equipments are basically to generate the parameters, which will be used for industrial towers, packed and tray towers. So, these laboratory equipments are called the module simulators, for the packed and tray towers.

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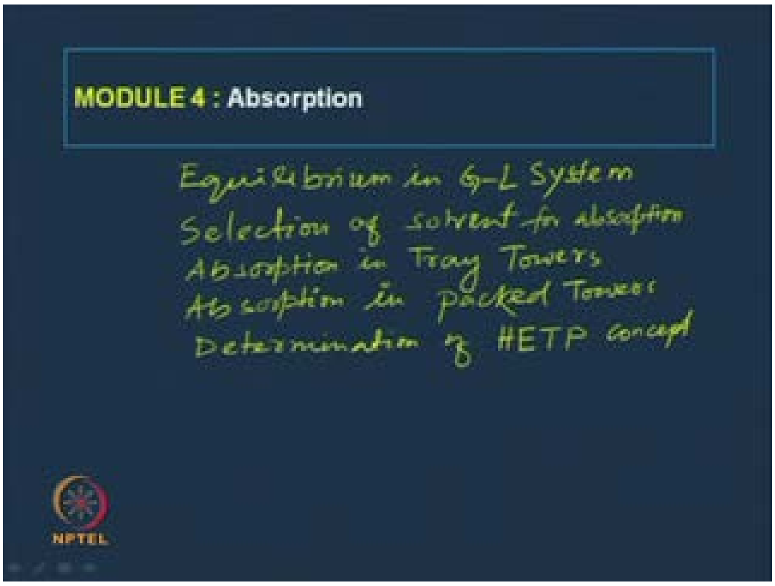

In module 4, we will discuss absorption, and in part 4 we will discuss equilibrium in gas liquid systems. equilibrium in gas liquid systems Selection of solvent for absorption. Absorption in tray towers, absorption in packed towers, determination of height equivalent to a theoritical plate HETP concept.

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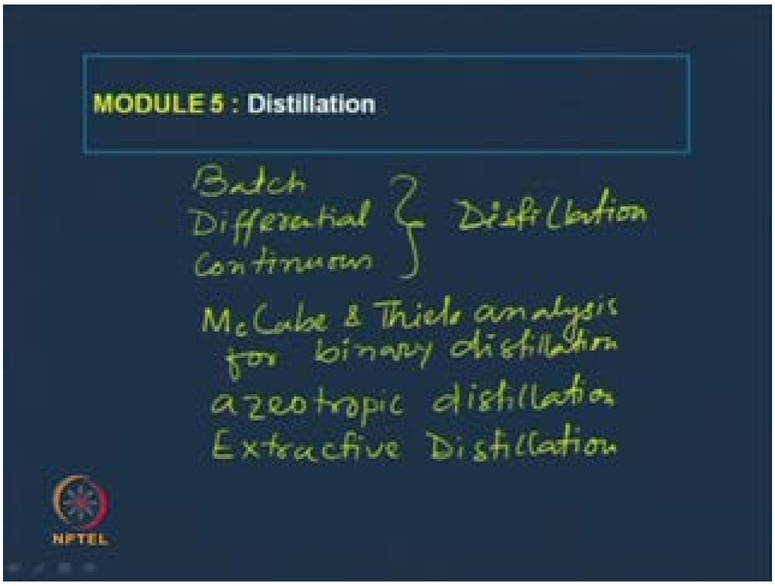

In module 5, we will discuss distillation, which is also very important mass transfer operation. Here we will discuss batch, differential and continues distillation. McCabe and Thiele analysis for binary distillation. Then we will be discussing azeotropic distillation and extractive distillation.

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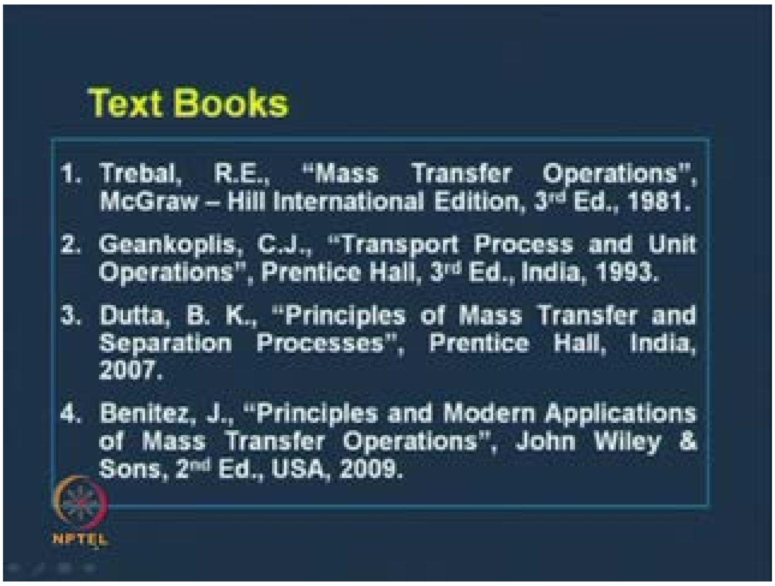

There are certain text books which we follow; Trebal R E, which is very important book for basic mass transfer operations. The title is mass transfer operations, McGraw hill international edition, third edition 1981. Second one is Geankoplis C J, transport process and unit operations, Prentice Hall publications 1993. Dutta B K, principles of mass transfer and separation processes, Prentice Hall India 2007. Benitez J, principles and modern applications of mass transfer operations. John Wiley and Sons, second edition USA 2009. So, these are the four text books we will mainly follow.

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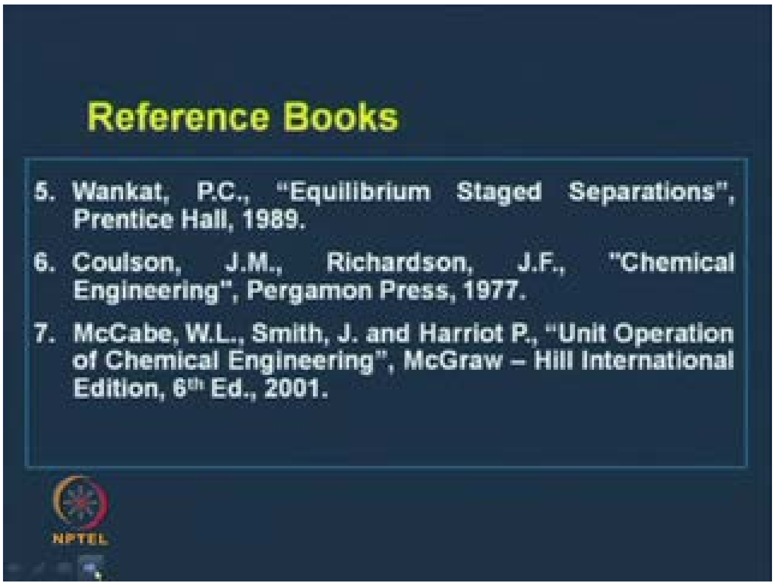

There are certain reference books; Wankat P C, equilibrium staged separations, Prentice Hall publication 1989. Coulson and Richardson, chemical engineering, Pergamon Press 1977. And other one is McCabe and Smith and Harriot, unit operations of chemical engineering, McGraw hill publications 6th edition 2001.

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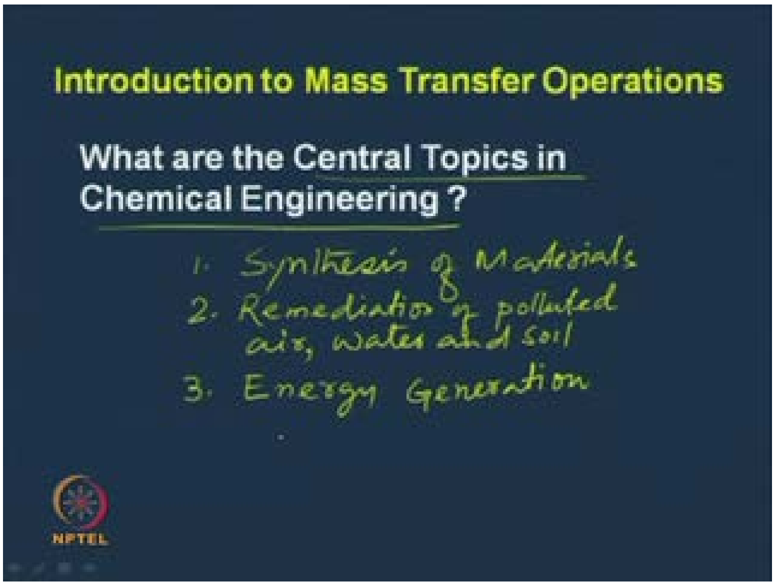

Now, we will discuss about the mass transfer operations. The first question which occurred in our mind, that what are the central topic in chemical engineering. There are three basic central topics, which we are more concerned. The first one is, synthesis of materials. Second one is, remediation of polluted air water and soil. And the third topic is energy generation. So, these three topics are very important for our survival, we need to synthesis materials, and we want our involvement should be free of pollutions. So, air water and soil should be free of pollution, and for our survival we need energy. So, energy generation is an important topic in chemical engineering.

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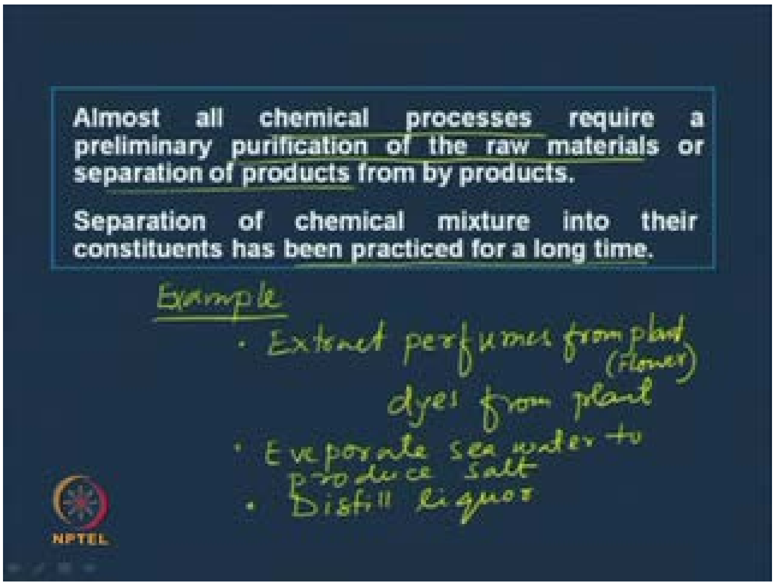

If we see, almost all the chemical processes, which require a preliminary purification steps of the raw materials, and also separations of the products from byproducts. Separations of chemical mixtures in to their constituents, is known a practiced for long time. For example, we extract perfumes from plant, particularly flower, we extract dyes from plant, we evaporate sea water to produce salt, and also we distilled liquor. So, these are the process, which we use for long time or practice, in our day to day life, and these are the examples of separation processes. If we consider the human body we can see, if we do not have the kidney, the human body could not function for a long.

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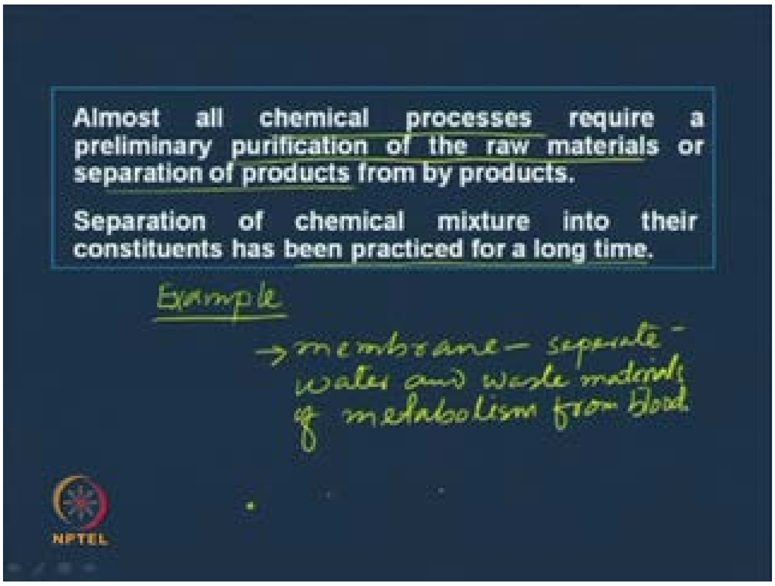

Here a membrane, which selectively separate water and waste materials of metabolism from blood.

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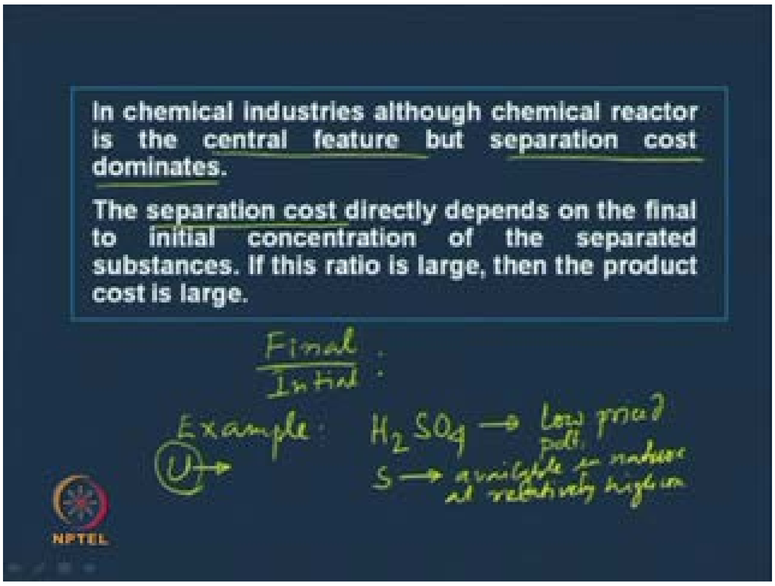

In chemical industries although chemical reactor is the central feature, but the separation cost dominates. This separation cost directly depends, on the final to the initial concentrations of the separated substances. If this ratio is large, then the separation cost is large. For example, we see sulfuric acid; this is low price product, because sulfur is available in nature at relatively high concentration, this is available in nature at relatively high concentration, whereas if we consider uranium, this is a costly material, because the uranium available in the nature is in relatively low concentration. So, in case of uranium, the final to initial ratio is large, so the separation cost for uranium is large.

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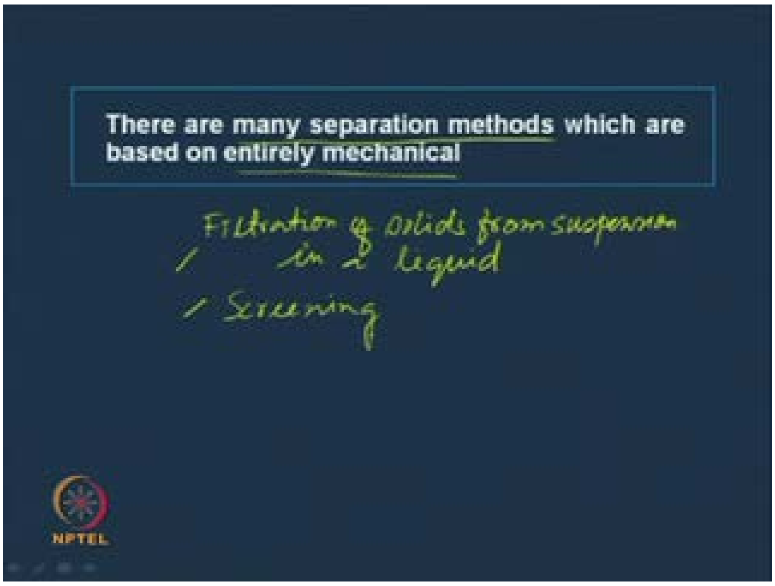

We chemical engineers want to separate the constituent of a mixture, in relatively cheaper price or economical way, and those are the process which we use, is far different from the laboratory scales. Like, if we want to separate hydro carbon mixture, one chemist they can use the chromo autographic technique to separate them, which will be costly. In case if you one to separate the same constitution of hydro carbon in industry, the chemically engineer will use, the distillation as a process, so economy considered are important part over hear. There are many separation method, which initially distain mechanically separation. For example, filtration of solid from sustention in a liquid, we use filter medium to flitted the solid of the sustention, so it is completely mechanically operator. Another one is that, if there is mixture of solid material, and we want to separate them in different sizes, we use screening as the process, by which we can often different high fraction of the particles, and this is also completely mechanical separation.

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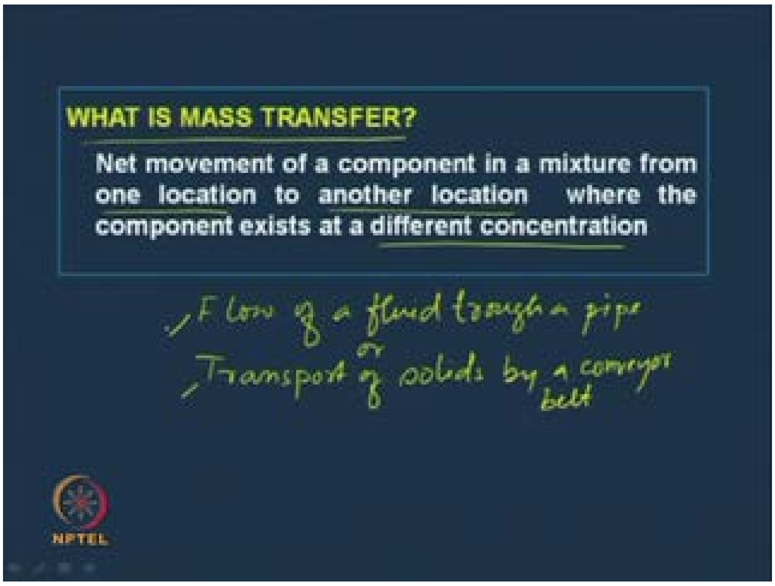

The separation where the change in concentration occurs, we call the mass transfer operation. Now what is mass transfer. It is late moment of the component in a mixer from one location to another location, where the components exist at different concentration, is the mass transfer operation. If we consider a flow of a fluid through a pipe, or transport of solid, by a conveyer belt, are these operations of mass transfer operations. No, these are not the mass transport operations.

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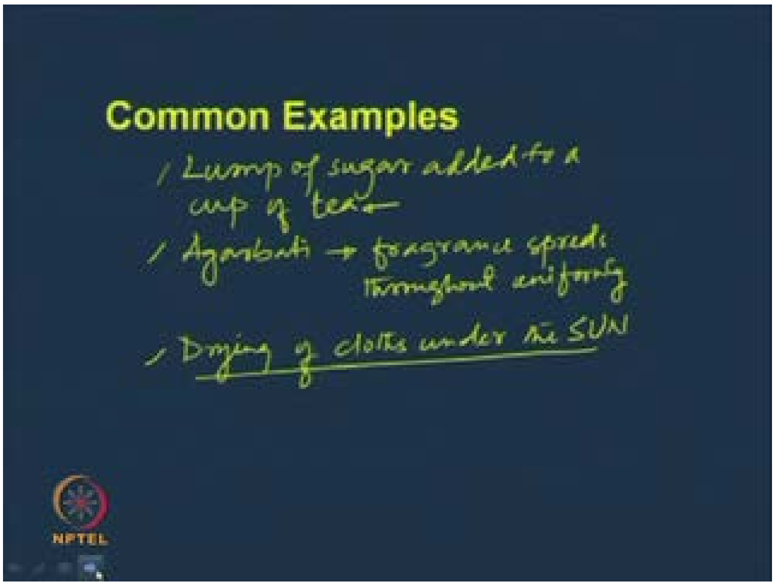

The common examples of mass transfer operation are, we can see at a lamp of sugar lamp of sugar added to a cup of cup of tea. So, in this case, the sugar dissolved in liquid and diffuses throw out uniformly. We use agarbati, where fragrance spread though out uniformly. Drying of clothes under the sun, here moisture defuses to the year, and this operation is also mass transfer operation.

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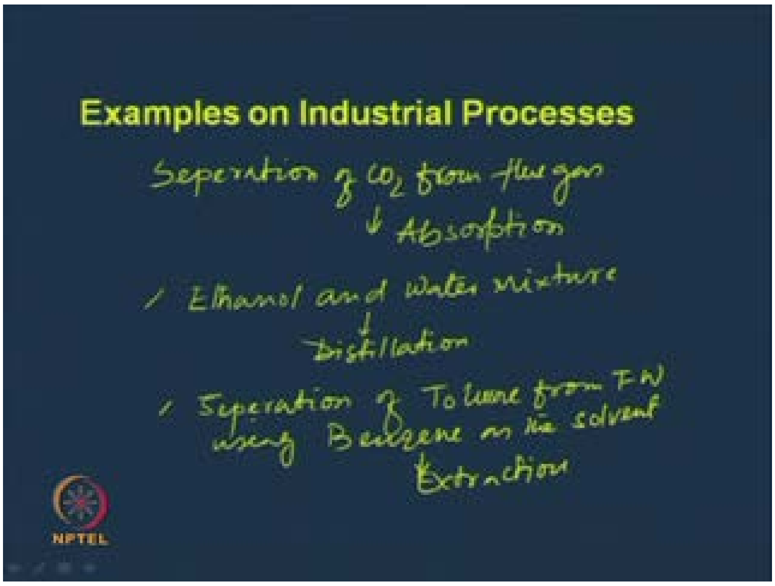

There are some industrial examples, the common examples are, superstation of CO 2 from flue gas. As you know CO 2 is a green house gas, and the major contributor of the, are emitter of the carbon day oxide, is the power plant. And the power plant of gas is comes out, contains huge quantities of CO 2, and we need to remove them from the flue gas for our safety in the environment. So, process you use to the separate CO 2, is the absorption process, or if we want separate ethanol and water mixer, and water mixer we use distillation to separate them. Later, we will discuss more detail on absorption, distillation separately, in module four and module five. Another common example is the separation of the toluene water mixer, from the toll owing water mixer from the toll owing water mixer using benzene as the solvent, and the process we use, is called extraction. So, these are the common example of industrial process.

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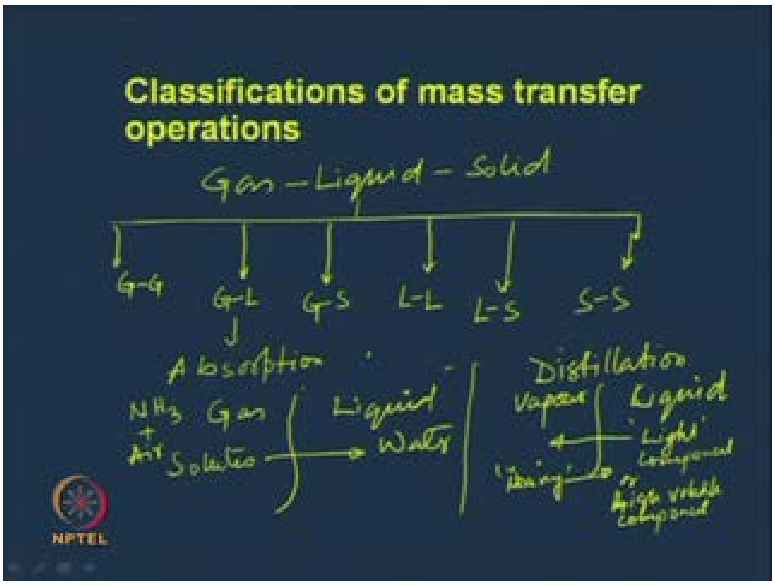

Now, let use classified mass transfer operations, if there are multiphase distance, as we know we have three phases; gas, liquid and solid. With these three phases, we can have six combination of face contact. So, one is gas gas system, the second one is gas liquid system, third one is gas solid system, forth one is liquid liquid system, fifth one is liquid solid system, and then solid solid system. With these six phases, if we considered gas gas system, we can see most of the gashes components; they are miscible in each other. So, this type of process, gas gas system is not practically realized. So, now if we considered gas liquid system, one of the examples of gas liquid system is absorption. Here if we considered a gas and liquid, to different phases are brought in to contact, then solutes from the gas phase, will transfer to the liquid stage.

It means the solutes are changing hands, from the gas phase to the liquid phase, and some of the component in the gas mixer will be preferentially dissolved in the liquid phase, and hence we will get a separation. For example, if we take ammonia and there mixer, and contact with the liquid water, then ammonia will preferentially dissolved in water, but no air. So, this is gas liquid system operation. Other example of gas liquid system is the distillation. In this case, the process is equilibrium state operations, and in each stage, the gas and liquid are in intimated contact similar to absorption. Here the transfer of solid take place in both the direction, the low volatile component or light component will go to the vapor phase. So light component or high volatile component will go to the vapor phase, and heavy are low volatile component will transfer to the liquid phase, and we will have a separations between the components. Now, considered the gas solid system, one of the examples of gas solid system, is the drying.

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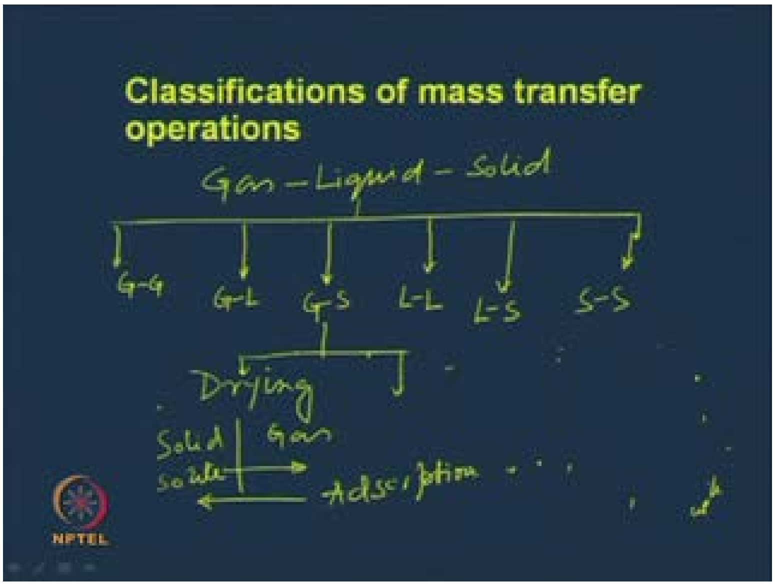

So, in this case also solid are changing hand between solid and the gas, so solid and gas system, where the solute transfers from the solid phase to the gas phase. Another one, is this transfer occurs in the reverse directions; that is from gas to the solid, then we call this absorption. Like, if we considered a mixer of hydro carbon, and we want to separate if we use activated carbon, then the constituents are absorbed in different proportion in the activated carbon, so we can have a separation in that respect. The other category of classification on the mass transfer operation, is the liquid liquid system.

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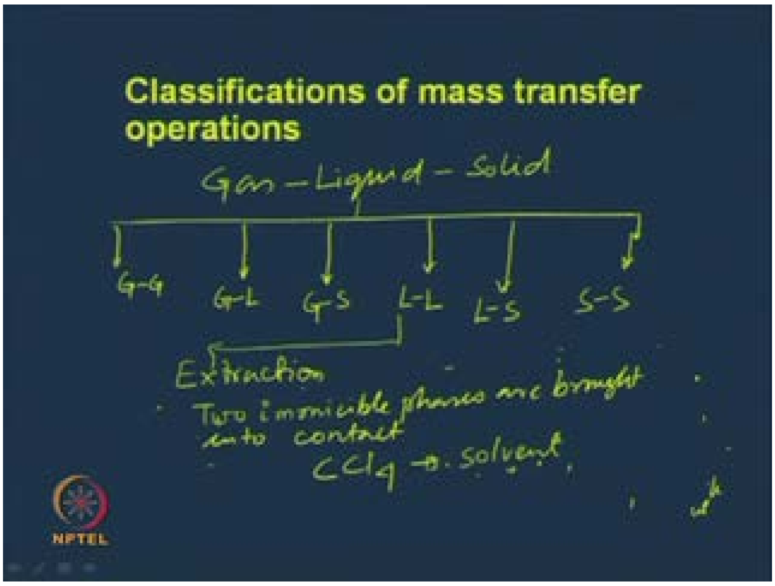

In this case, one of this liquid liquid system is the extraction, here the two indictable phases are brought into contact, and the depending on their solubility in individual phases, the components are separated. For example, if we want to separate acetone from acetone water mixer, two immiscible phases are brought into contact. For example, if we want to separate acetone water mixer to separate acetone, we can use carbon tetra chloride CCl 4, as the solvent or another phase to extra acetone.

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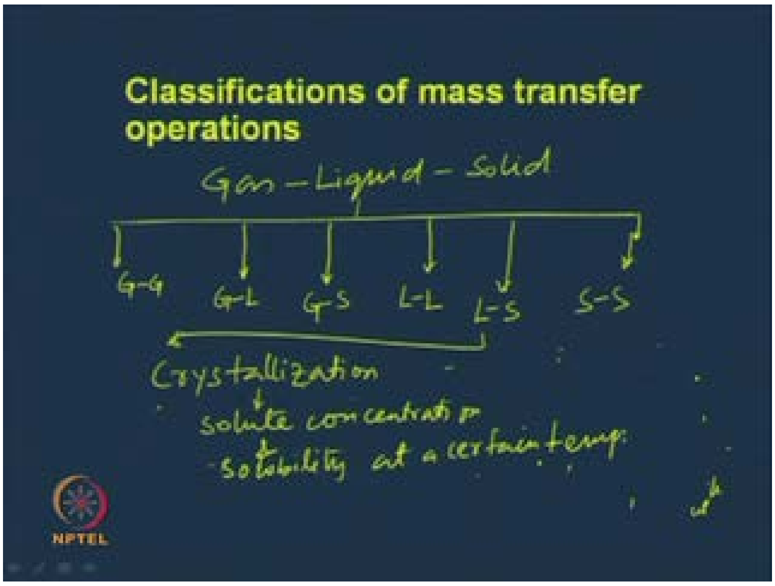

The other category is the liquid solid system. So, in case of the liquid solid system, one of them the example is crystallization, and this is the process of formation of the solid from a liquid solution, based on the different in solid concentration, and the solubility at a shorten temperature. Like if we want to obtain sugar, which is an important component of our diet, we want to evaporate the cane sugar solution, and to get the systole sugar. Like, if we one to often salt; sodium chloride or brine, what we do? We use the brine solution and get salt crystal. So, these are the example of the crystallization.

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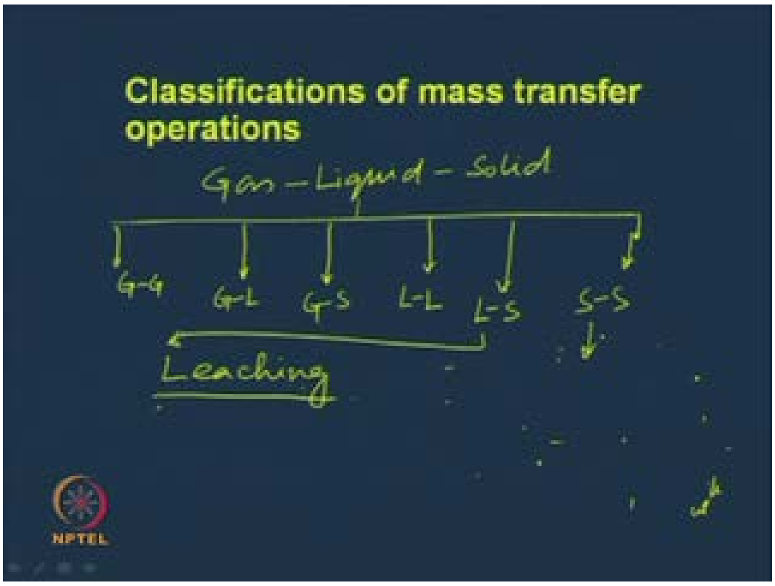

Other types of liquid solid system are the leaching. Here we use a selected solvent, to separate the component in the solid mixture; for example, free extract over using a liquid solvent. And the last category is the solid solid systems, since the diffusion in solid solid system is very low, so this process is not commercial valuable.

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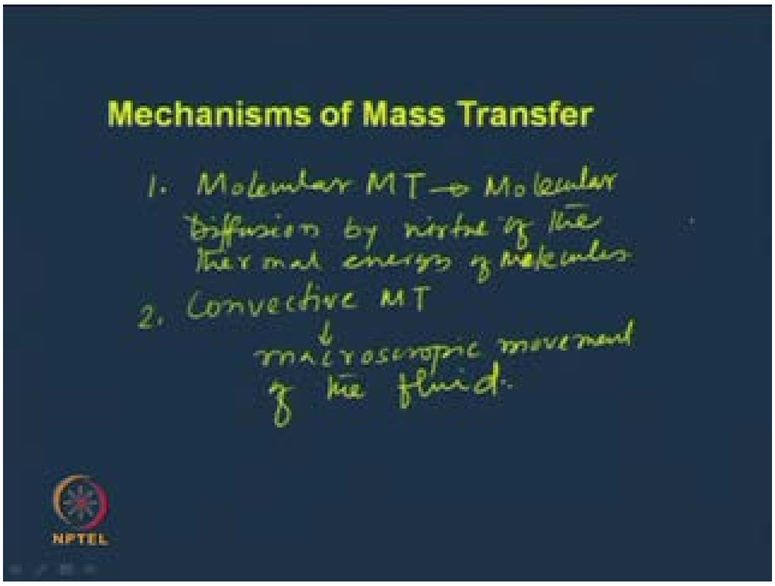

So, next will discuss what are the mechanisms of mass transfer? There are two basic mechanisms for mass transfer; one is molecular mass transfer, and the second one is convective mass transfer. Molecular mass transfer occurs by molecular diffusion, by virtue of the thermal energy of the molecule. Conductive mass transfer occurs, by random and macroscopic moment of the fluid. Next we want to know, what are the driving force or what is the driving force for mass transfer. To understand the driving force mass transfer, let us considered the system between in gas and liquid.

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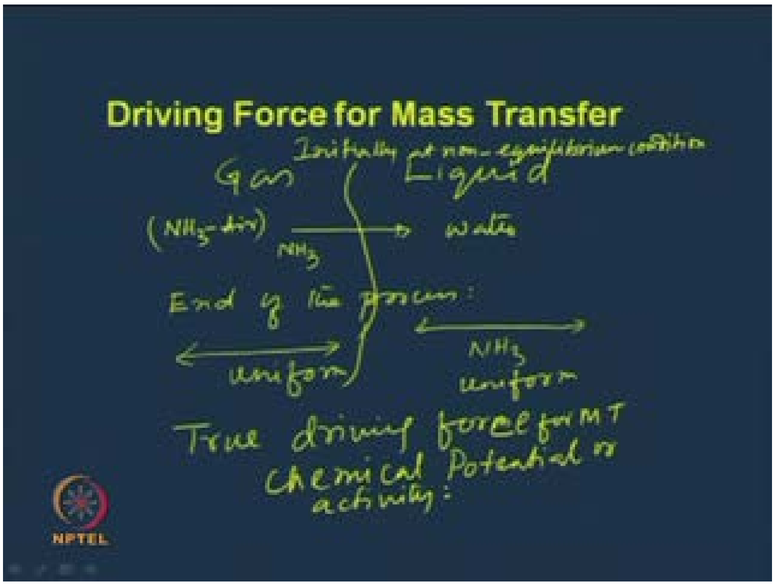

So, in this case the system at the beginning, initially at non equilibrium condition. Suppose, if we take same examples of ammonia, and we are mixer, and we take water and the solvent. So, when the system initially not at equilibrium, the continuous change of the property by molecular diffusion take place, and change of the concentration occurs and ammonia diffuses and dissolved in water. So, this process will continue, until the equilibrium is reached. So, at the end of process what we see, we see that the ammonia concentration in the gas phase is uniform, whereas in the liquid phase also ammonia concentration is uniform, but they are in different values. In each phase they are uniform in concentration, but the value vary from the gas phase to the liquid phase, but the equilibrium is reached and system reaches study state.

So, then what is the true driving force for the mass transfer. If we see the chemical potentials of ammonia in liquid, as well as in the gas phase, both are same, or the activity of the component are same in the both phases. So, true driving force for mass transfer, is the chemical potential or activity, but for multiple phase system, we generally deal with the diffusional process in each phase individually, and each phase, concentration is the driving force for mass transfer. So, this is end of lecture one, in the next lecture, we you including you to the molecular diffusion and it application.

Thank you