Principles and Practices of Process Equipment and Plant Design
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Module - 02
Lecture - 04
Introduction to Mass Transfer Processes

Hello everybody. So, in the introductory session on the course on Principles and Practices of Process Equipment and Plant Design, you are instructed or rather you are told regarding the different types of processes and what are the means, under what conditions, which processes are applicable. Then, exactly what does the design comprise of, what are the basic steps of design, and how you will proceed with it!

So, after this today we have come to the 2nd module, where we will be discussing Mass Transfer Processes, specifically we will be discussing separation processes.

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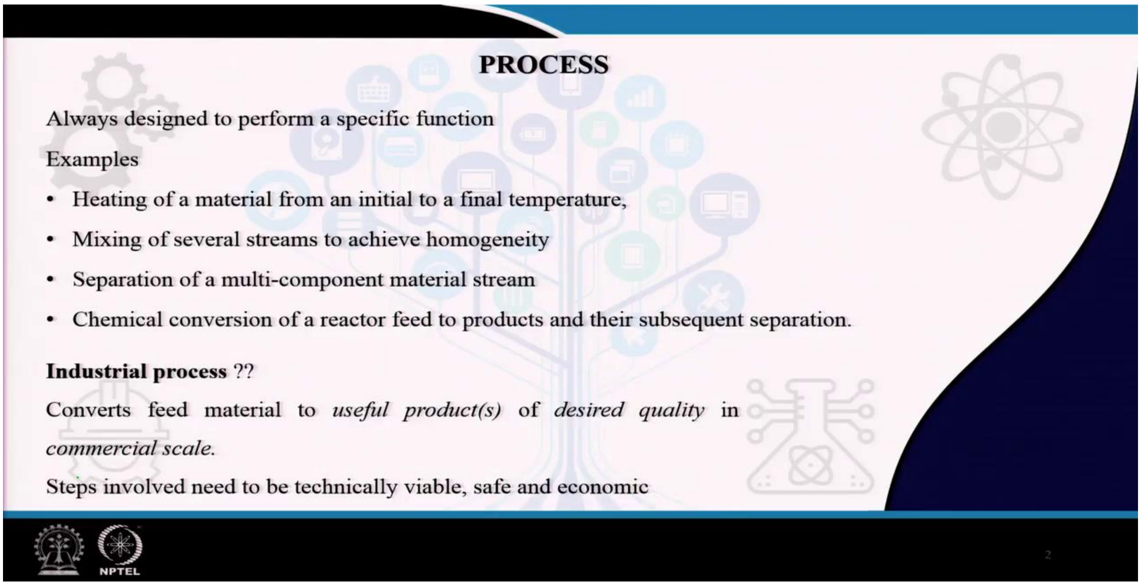

PROCESS

Always designed to perform a specific function

Examples

- Heating of a material from an initial to a final temperature,
- Mixing of several streams to achieve homogeneity
- Separation of a multi-component material stream
- Chemical conversion of a reactor feed to products and their subsequent separation.

Industrial process ??

Converts feed material to *useful product(s)* of *desired quality* in *commercial scale.*

Steps involved need to be technically viable, safe and economic

Now, when we say if I will just start from the slide which Professor Ray had shown in the last discussions that what is a process? It was said that among the different processes that he had highlighted upon there were two specific things that were mentioned, one was the separation of a multi-component material stream, and the other was the chemical conversion of a reactive feed to products. Then the products and the reactants had to be separated. So, we find that as chemical engineers there are a large number of processes both reacting as well as non-reacting where we encounter different types of separation processes.

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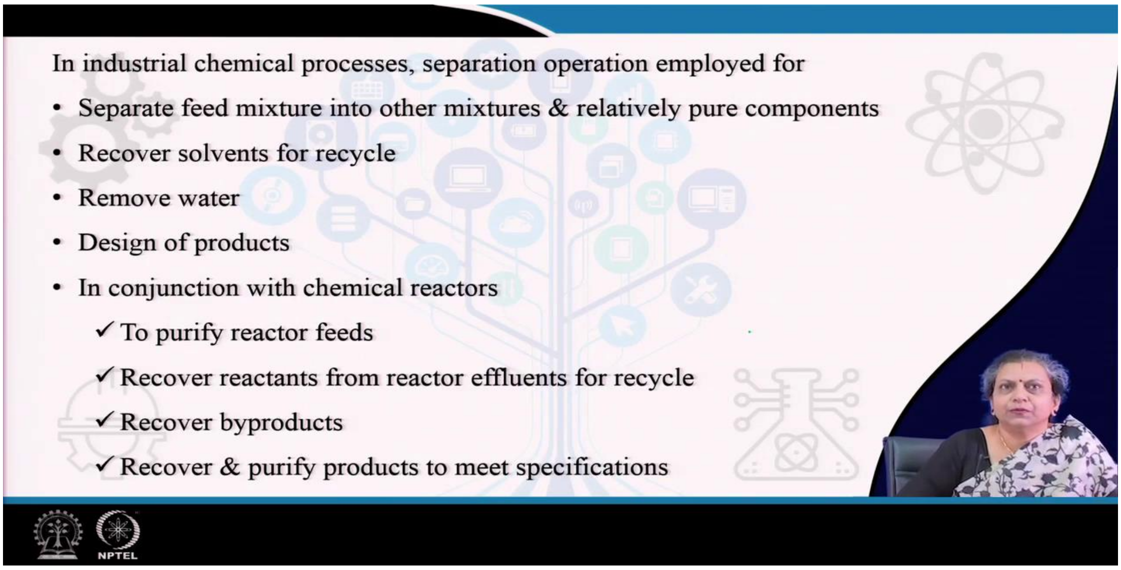

In industrial chemical processes, separation operation employed for

- Separate feed mixture into other mixtures & relatively pure components
- Recover solvents for recycle
- Remove water
- Design of products
- In conjunction with chemical reactors
  - ✓ To purify reactor feeds
  - ✓ Recover reactants from reactor effluents for recycle
  - ✓ Recover byproducts
  - ✓ Recover & purify products to meet specifications

Now, these separation processes are often employed for separating feed mixtures into other mixtures or relatively pure components just like the reactor feed has to be separated from the un-reacted feed has to be separated from the products. Then suppose you are recovering some particular chemicals or some particular components by using a solvent. Then you need to recover the solvent and recycle it. Sometimes, you need to remove water. Sometimes, you need to design several products which exploit the process of separation or rather the principles of separation processes. A classical example of this is the coffee which is made in the espresso machine.

Now, all of you would agree that this coffee is much tastier than the filter coffee that we have. The primary reason is that at a very high temperature and pressure for a very short while say about 20 to 30 seconds water is made to come in contact with the coffee beans and it leeches out specifically those particular chemicals, which are responsible for the aroma and the cream and the sweetness of the coffee that is made. It leaves behind the materials which are responsible for the acidity and the bitterness etc. Now, a proper design of the coffee machine will contribute to a tastier coffee.

So, this is one particular everyday example, where separation processes are used for the preparation of products. Then definitely see when we, as chemical engineers, very frequently deal with several sorts of reacting systems. In all these reacting systems as I have already mentioned a few minutes back that we need to purify the reacted feed before the feed is fed into the reactor, we need to recover the un-reacted reactants from the reactor effluence, and then they are needed to be recycled. We need to recover the by-products and we also need to recover and purify the products, which we have obtained from any process to meet the specifications.

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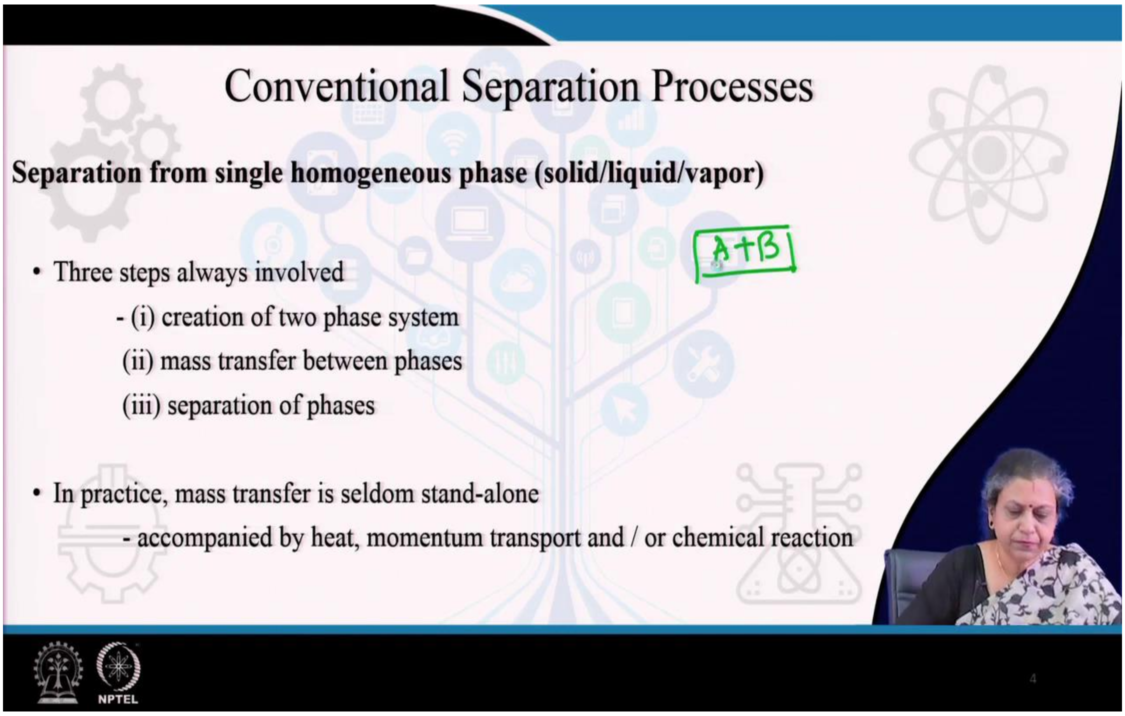

Conventional Separation Processes

Separation from single homogeneous phase (solid/liquid/vapor)

- Three steps always involved
  - (i) creation of two phase system
  - (ii) mass transfer between phases
  - (iii) separation of phases
- In practice, mass transfer is seldom stand-alone
  - accompanied by heat, momentum transport and / or chemical reaction

Now, among the different separation processes, there are some processes where we are required to separate say a heterogeneous mixture say a mixture of two immiscible substances. In this case, the separation is slightly easier I should say we can exploit gravity or the centrifugal force and even electrical forces, filtration, etc. and we can bring about the separation.

After the separation what do we have? We have a homogeneous substance. Now, in this homogeneous substance, it is comprised of different components. Now, if we would like to separate these particular components from a homogeneous mixture; the homogeneous mixture can be either in the liquid phase it can be in the vapor phase, right.

So, when we have to separate such a homogeneous mixture then what are the principles that we apply, specifically in this particular module we will be discussing those principles. Now, suppose we have a homogeneous system, now when I suppose I have to say one particular mixture, which comprises of say binary mixture say, for example, it comprises of A and B and its homogeneous.

So, now I would like to separate say B from A either I would like to purify A or I would like to recover B from the mixture of A and B. So, what do I do to achieve this? The first thing is if B has to be removed from A then I need to introduce another second phase which is preferentially going to take a B. So, that B is recovered from A.

Now, this second phase has to be created or it has to be added. Once the second phase is introduced into the mixture of A and B and I want to recover B. So, therefore, definitely, the second phase is expected to have a greater affinity for B as compared to A.

So, therefore, the two phases come in contact, and then they are kept in for a sufficient time in contact, such that mass transfer occurs between the two phases, and then subsequent the two phases are separated. So, therefore, in these processes which we will be specifically dealing with in this particular module, they are the separation processes to separate components from a single homogeneous phase.

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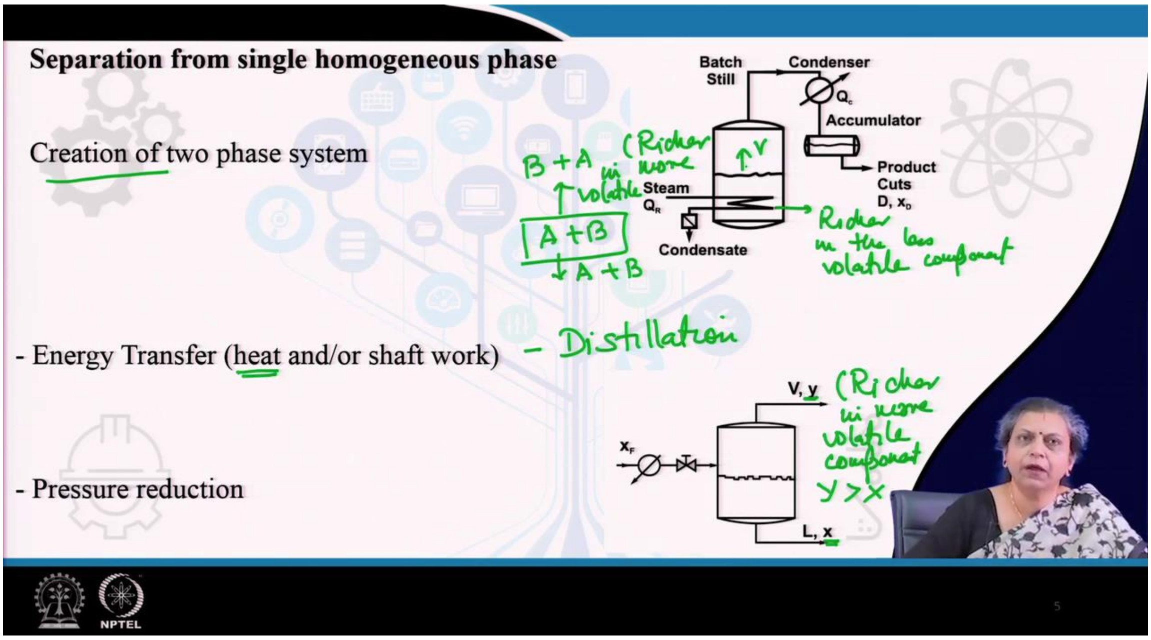

Separation from single homogeneous phase

Creation of two phase system

- Energy Transfer (heat and/or shaft work) - Distillation

- Pressure reduction

So, therefore, the first challenge we know is to create the phase. how do we go about creating the phase? Say once very conventional way which it is the most commonly practiced technique in industries is by energy transfer usually it is by heat transfer. What do we have? We have the mixture in say particular steel and we heat the mixture, we can heat it either by introducing a heating coil or using steam, we can heat it by any particular means.

The moment we heat it, what happens? The liquid which is there partially vaporizes; when it partially vaporizes and the vapor is formed, quite naturally the vapor will be richer in the more volatile component. So, therefore, the vapor which is richer in the more volatile component, rises leaving behind a liquid that is richer in the less volatile component.

This particular vapor rises, it is condensed and it collects in the accumulator where we receive a product quite naturally this product is richer in the more volatile components. It leaves behind another product in the steal, which is richer in the less volatile component.

So, this is one particular way by which a second phase rather vapor phase has been created from a liquid phase by application of heat, and the vapor phase has been obtained by partially vaporizing the liquid feed. So, heat separates the liquid into more volatile components which have been obtained as a product leaving behind the less volatile components.

So, among A and B the example, which I was citing so, suppose the mixture comprises of A and B and B is the more volatile component. So, definitely in the vapor, we will have both A and B, but we will have a greater proportion of B here and a lesser proportion of A. And the liquid which will be lying here naturally will be richer in A having a lesser proportion of B, right?

Same thing we can also do by partially condensing a vapor feed. If we condense a vapor feed partially then naturally what we get, we get the liquid which is richer in the less volatile component and the more volatile components remain in the vapor phase. So, therefore, the creation of two phases they can be; it can be achieved and it is achieved most conventionally in industrial systems by majorly heat transfer it may or may not be accompanied by shaft work, and this process is known as distillation. There are different types of distillation which we will be discussing after we complete the introduction and certain other discussions regarding separation processes.

Now, apart from energy transfer suppose we have a liquid feed, this liquid feed we suddenly reduce the pressure of the liquid feed is sent through say a throttling valve where the pressure is suddenly reduced.

The moment the pressure is reduced, what happens? The liquid will partially vaporize. The vapor which vaporizes and the liquid which remains, two are under equilibrium conditions and the vapor naturally will be richer in the more volatile component and the liquid will be richer in the less volatile component.

So, therefore, the vapor composition, generally in the vapor, the composition of the more volatile component is denoted by y and the composition of the more volatile component in the liquid is denoted by x. So, and by this particular process, we always obtain y to be greater than x. So, this is one particular way of attaining the separation of components from a single homogeneous phase.

Definitely in this particular process, what do we get? We find that the vapor is created from the liquid itself and since it is created from the liquid itself, we find that the components which are available in the liquid phase are the same are available in the vapor phase as well.

So, therefore, there are no chances of the product being contaminated, but there are also certain situations where distillation is not very feasible. It is quite evident that distillation exploits the difference in the boiling point of the two components. So, therefore, if the boiling points are quite far off then definitely the vapor that we will have a much greater proportion of the more volatile component.

If the boiling points are very close, then definitely the separation that we will be getting will be much less. Further, under that condition, we have to repeatedly perform this process. Now suppose for getting a feasible amount of separation, if we have to use a very large number of stages, then under that condition distillation is not economically feasible.

When we were discussing the introduction, it has been told to you and you have realized that economics governs the choice of optimum process parameters. So, therefore, in distillation will not be economically viable, we have to look for some other processes. There are also certain situations, where distribution will not be feasible.

For example, if the components, which make up the homogeneous phase, form an azeotrope, under the conditions of temperature and pressure when distillation is being performed. If that happens then definitely as you know that heat during an azeotropy the vapor boils with the same composition as the liquid.

So, therefore, no separation between the liquid and vapor is possible beyond the azeotropic composition. So, under those conditions when we cannot separate the two components of a homogeneous mixture by creating a phase, either by application of heat or by pressure reduction, then, in that case, we have no option we have to add the second phase.

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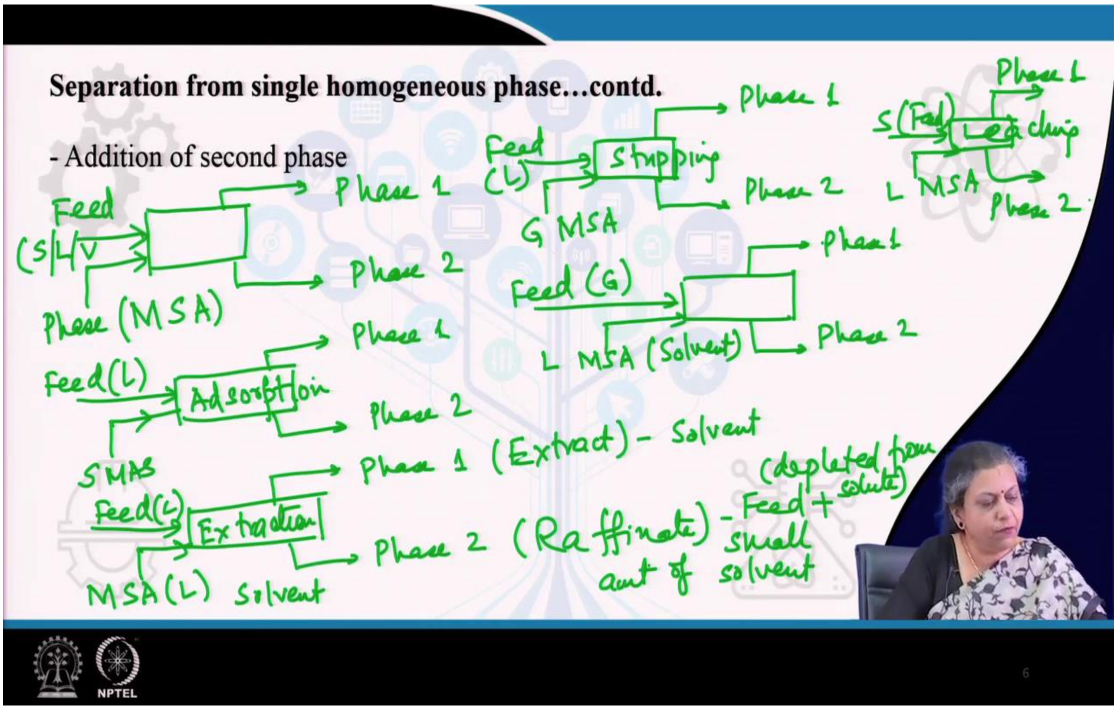

Separation from single homogeneous phase…contd.

- Addition of second phase

Now, when we add the second phase say suppose we have got a feed right we add a second phase and auxiliary phase or the second phase we add here. It can also be said as a mass separating agent we added. And then what happens? This particular mass separating agent will have more affinity towards some components of the feed as compared to the other components.

So, naturally, the feed and the mass separating agent are introduced here and they are allowed to be in intimate contact, such that mass transfer occurs between them. Then finally, the two phases are separated, this is also one other way of performing the separation.

Now, this feed as I have said feed it can be solid, it can be liquid, it can also be vapor or a gas. For a liquid feed, what is the MSA that we can add? We can add either a solid. When we add a solid MSA, it adsorbs certain components from the liquid feed, the process is known as adsorption.

Generally, during adsorption, we introduce the feed through a solid bed. we do not introduce the solid as well as the feed together inside the bed except under certain conditions, which is known as the fluidized bed. Normally, the solid is inside the unit, the liquid flows through it, and then certain components of the liquid get adsorbed here. Then the liquid, which is depleted of those components it comes out.

We can also introduce an MSA, which is also a liquid, for a liquid feed that will be immiscible in the first liquid. So, under this condition, the liquid which has been introduced along with the feed again extracts some portion of the components from the liquid. Then naturally we get two products, one product will be richer in some components the other product will be richer in some other components. Generally, the liquid MSA is termed as the solvent. This solvent extracts some amount or rather some particular components more than the other components.

The product which we get is normally known as the extract. The extract contains a greater portion of the solvent and maybe some portion of the main liquid in the feed and a greater portion of the component, which it is supposed to extract. The remaining liquid which remains of the feed after the component has been extracted is known as the raffinate, which primarily comprises the feed. There may be a small amount of solvent in the raffinate. It is because we hardly get liquids which are completely immiscible with one another.

So, the raffinate contains a small amount of solvent and feed which is depleted from the solute as a good amount of solute has gone into the solvent which forms the extract. So, therefore, if we have a liquid feed, we can perform different operations. Either we can perform adsorption when the MSA is solid or extraction when the MSA is liquid.

We can also introduce a gas phase here, a gaseous MSA. Under this condition, the gas preferentially strips out certain components from the liquid and then we get two products, product one and product two. The gaseous product will be richer in the components that it has stripped off from the liquid. So, this process is known as stripping.

So, therefore, in the same way, suppose we have a gaseous feed. In that gaseous feed, what can we add? We can add a liquid MSA, this liquid what it does? It preferentially dissolves some particular components of the gaseous feed that are more soluble in the liquid MSA as compared to the others.

So, therefore, from here we get two products, a gaseous product, which is depleted from the more soluble components, and a liquid product that is richer in the more soluble components. Generally, when we add a liquid MSA it is known as a solvent.

We can also have a solid feed and we can introduce a liquid MSA. So, therefore, this is just the reverse of the adsorption process and in this particular case what happens is the liquid can leach out some particular components from the solid feed. Just the way water had leached out the favorable components from the coffee beans to give you the cup of coffee. So, therefore, in this particular case, the process is known as leaching. Right here, we also get two products i.e. product 1 and product 2.

So, therefore, when it is not possible to create a product by addition of energy or reduction of pressure then in that case we create the 2nd phase by adding a 2nd phase to the feed. Therefore, when the feed is solid we can add a liquid to it and we can perform the process of leaching, when the feed is a liquid we can add a liquid that is immiscible with the feed liquid and perform the process of extraction.

We can add solid which preferentially adsorbs some particular components and we can perform the process of adsorption. We can add a gas that preferentially strips off some particular component from the liquid feed and this process is known as stripping. Adsorption of water vapor from air by drying off air rather that is a very well-known adsorption process.

Then, dissolution of carbon dioxide from a carbon dioxide air mixture by the addition of a means or water. This is a very standard or well-known adsorption process. If you have a toluene, and acetic acid mixture and to add water to preferentially remove acetic acid from toluene. So, this is also this is an extraction process.

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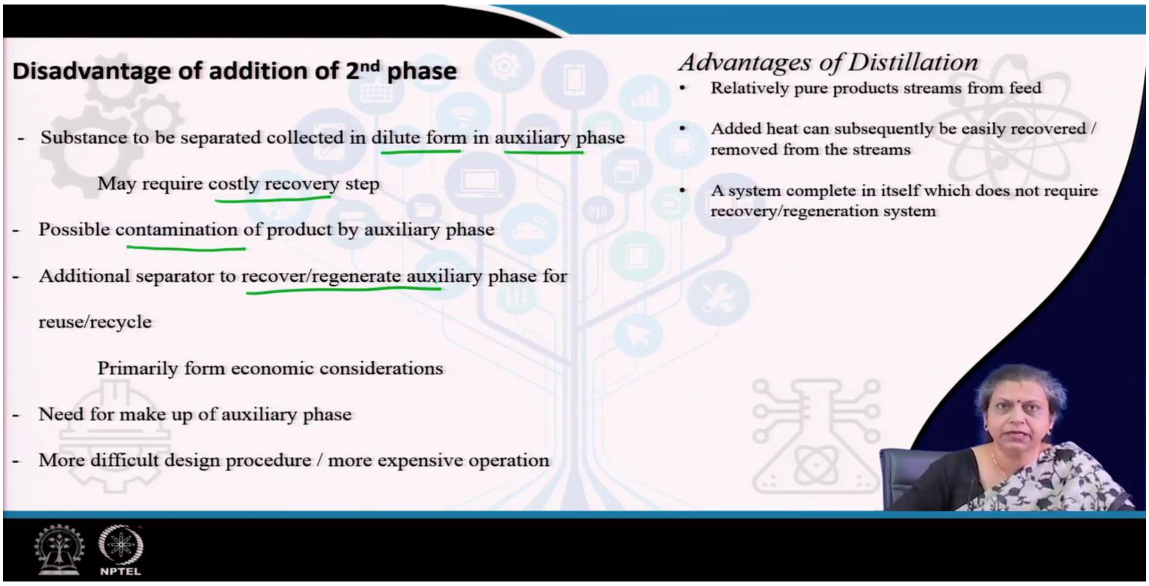

Disadvantage of addition of 2nd phase

- Substance to be separated collected in dilute form in auxiliary phase
  - May require costly recovery step
- Possible contamination of product by auxiliary phase
- Additional separator to recover/regenerate auxiliary phase for reuse/recycle
  - Primarily form economic considerations
- Need for make up of auxiliary phase
- More difficult design procedure / more expensive operation

Advantages of Distillation

- Relatively pure products streams from feed
- Added heat can subsequently be easily recovered / removed from the streams
- A system complete in itself which does not require recovery/regeneration system

Therefore, these are different ways by which we can add a second phase and we can effect mass transfer between the two phases, and the separation can be achieved.

There are certain things, which you need to remember when you are adding the second phase. In that case, you find that the products that you get, the component that you have removed from the feed that component is dissolved or that component is in association with the MSA. So, the product that we get is definitely in a much more dilute form in the MSA or the auxiliary phase.

Therefore, if we need to remove the product from here, we may encounter a costly recovery step which we have to keep into mind when we design the process by the addition of a second auxiliary phase.

Since the product is or rather the desired component is in association with the auxiliary phase. So, it is it there are chances of possible contamination of the product by the auxiliary phase and you must remember that we need to recover the MSA and recycle it for an economic operation of the process. So, therefore, additional recovery and regeneration of the auxiliary phase have to be considered when we design such a process.

Definitely, in the whole process there will be some amount of auxiliary phase which will be lost, right? Suppose it is a liquid and some amount of liquid will be volatilizing with the vapor phase. If there is some amount of vapor then that may be carried with the liquid.

So, therefore, we need to keep on having some particular makeup facility to make up the auxiliary phase which is lost by this process. So naturally, it's quite evident that we would design a procedure that will be more difficult and the operation will also be more expensive under this condition. So, just as distillation is complete in itself. It does not require or recovery or a regeneration system, but when we add an MSA we need to keep this in mind.

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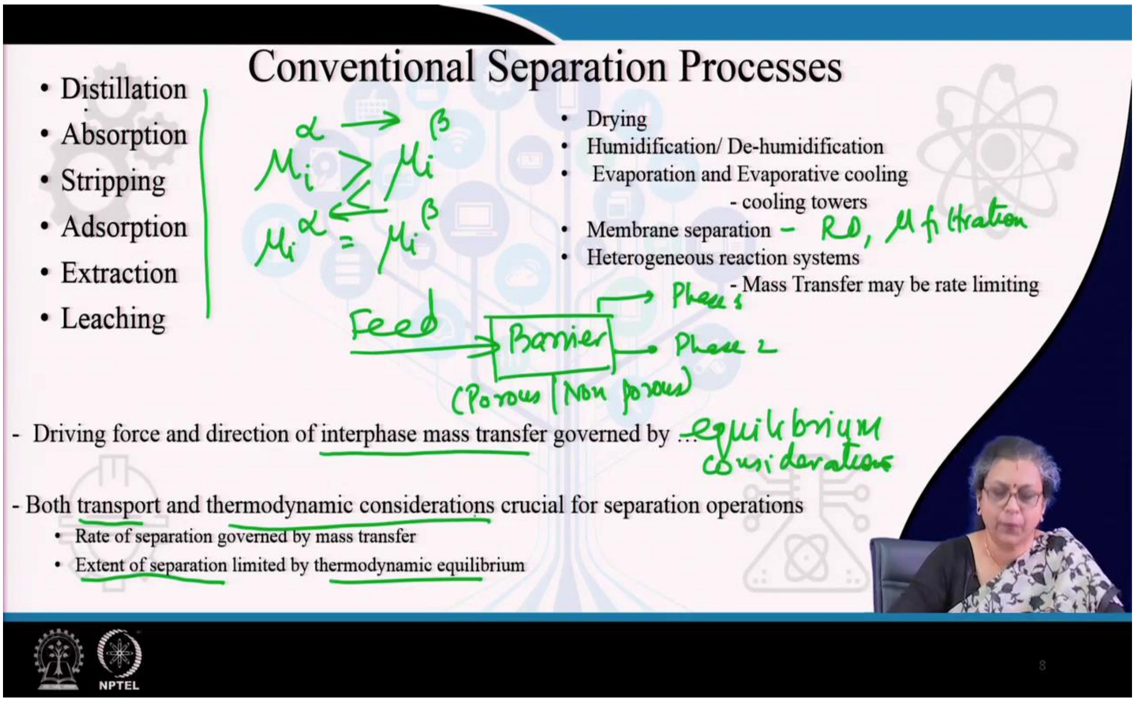

Conventional Separation Processes

- Distillation
- Absorption
- Stripping
- Adsorption
- Extraction
- Leaching

$$\mu_i^{\alpha} \xrightarrow{} \mu_i^{\beta}$$

$$\mu_i^{\alpha} \gtrless \mu_i^{\beta}$$

$$\mu_i^{\alpha} = \mu_i^{\beta}$$

- Drying
- Humidification/ De-humidification
- Evaporation and Evaporative cooling
  - cooling towers
- Membrane separation – RO, μ filtration
- Heterogeneous reaction systems
  - Mass Transfer may be rate limiting

- Driving force and direction of interphase mass transfer governed by ... equilibrium considerations

- Both transport and thermodynamic considerations crucial for separation operations
  - Rate of separation governed by mass transfer
  - Extent of separation limited by thermodynamic equilibrium

Now, here I would also like to mention that there are some other processes also which are multi-phase separation processes, but we are not considering those processes in this case. For example, suppose in case of evaporation what happens? There is some amount of liquid that volatilizes into the air in the vapor phase.

But in this case, it is important to remember that the rate of mass transfer which occurs in this particular case, that is not governed by the equilibrium considerations. What are the equilibrium considerations? For all the processes; that we have discussed in these processes how much amount of the component will be transferring from one phase to the other depends not only on the concentration difference of the component in the two phases but the difference in chemical potential of the component in the two phases. That for all these processes we find that the mass transfer between the two phases will occur as long as the chemical potential of the component will be equal in two phases.

Let say, the chemical potential of the component ‘i’ in Phase α is μ_i^α and in phase β is μ_i^β. The mass transfer will happen as long as either $\mu_i^\alpha > \mu_i^\beta$ or $\mu_i^\alpha < \mu_i^\beta$. The mass transfer will stop when $\mu_i^\alpha = \mu_i^\beta$. The mass transfer will always happen from the high chemical potential phase to the low chemical potential phase.

So, therefore, in all the processes that I have discussed, we find that they are governed by interface mass transfer, and this particular interface mass transfer is governed by equilibrium considerations. Other multi-phase mass transfer processes are, just like evaporation I was mentioning, not governed by equilibrium considerations.

Say for example drying, definitely in drying what happens? We have a flowing warm air and some liquid that vaporizes here. So, while we design a dryer, we do not take into consideration the equilibrium between the liquid, which is evaporating, and the liquid which is contained in the flowing air. Because there are a lot of other things which become much more important here.

For example, the temperature of the air, the velocity of the air, and the rate of diffusion of the liquid from the inside of the solid to the surface. So, there are a large number of things. The liquid will continue to vaporize into the air or into the flowing gas stream as long as the vapor pressure in the liquid is greater compared to the partial pressure of the liquid in the gas stream. But the equilibrium consideration does not govern while design of dryers and it is too difficult to get this equilibrium data.

The same thing is true for heterogeneous reacting systems as well. We may have to say suppose two particular phases for the reactants are in two phases, one reactant has to diffuse into another phase for the reaction to take place and in that case, we assume that the reaction is very fast so that this interface mass transfer governs the rate. But in this case, also the equilibrium considerations do not come during the design of the reactor. In this case, we define an apparent rate of reaction, which takes into account mass transfer, but that is a completely different procedure.

The same thing happens for membrane separation as well. During membrane separation what do we have? We have got a feed, the feed is made to move through some particular barrier may be a porous barrier or a nonporous barrier, and what does this barrier do? This particular barrier either restricts or enhances the movement of certain species with respect to the other species. Accordingly, we get a phase 1 and phase 2. But again in this case among this membrane separation process, we can have reverse osmosis, we can have microfiltration, ultra-filtration. All sorts of membrane separation processes, which are also not governed by any equilibrium considerations.

So, therefore, I repeat in this particular module, we will be discussing those separation processes for which the interface mass transfer occurs and this interface mass transfer is governed by equilibrium considerations. Therefore, for designing such mass transfer processes, the extent of separation is limited by thermodynamic considerations.

That is determined by the chemical potential of the component in the two phases between which the mass transfer is supposed to take place. While on the other hand, the rate of separation is governed by mass transfer. So, for the design of these particular separation processes which I have listed up here. For the design of those separation processes, we need to consider both transport as well as thermodynamic considerations.

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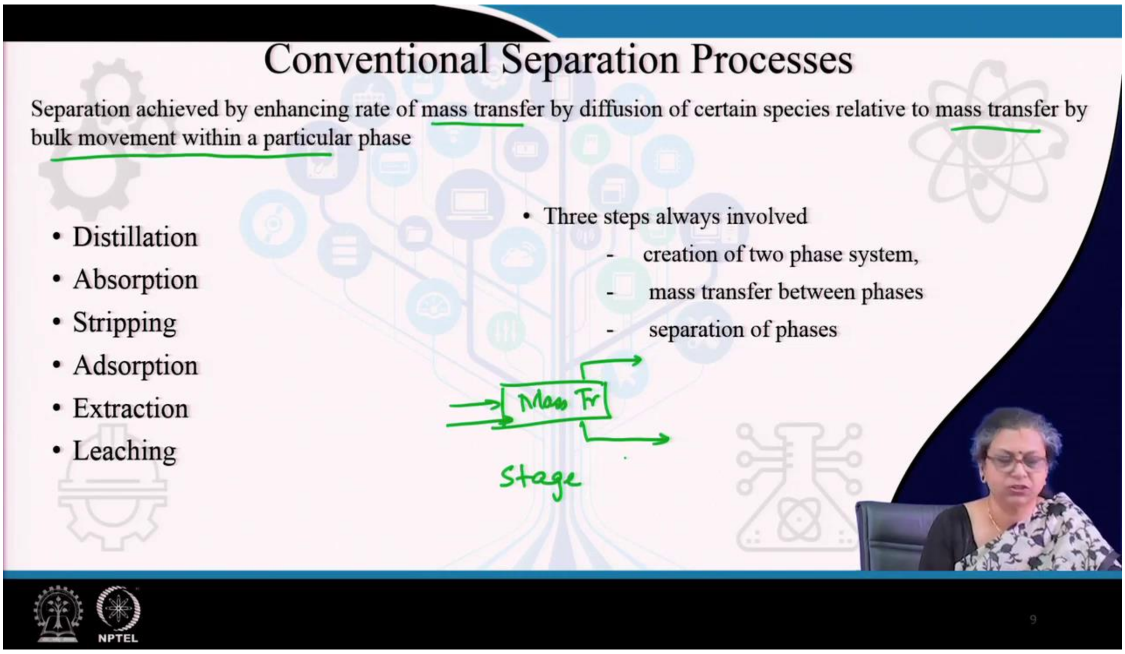

Conventional Separation Processes

Separation achieved by enhancing rate of mass transfer by diffusion of certain species relative to mass transfer by bulk movement within a particular phase

- Distillation
- Absorption
- Stripping
- Adsorption
- Extraction
- Leaching

- Three steps always involved
  - creation of two phase system,
  - mass transfer between phases
  - separation of phases

The separations are achieved for certain components by interface mass transfer and this particular rate of mass transfer is faster compared to the mass transfer which occurs due to bulk movement within a particular phase.

In shorts, the interface mass transfer rate must be much faster as compared to the mass transfer occurring by bulk motion. Therefore, in all these processes, we either create or add the two phases, and then mass transfer occurs in some particular equipment or a combination of equipment and then we achieve separation.

This entire process comprises one stage of the separation process. What is the maximum separation that we can achieve in one stage? In between these two effluent products the component which has to be separated is in equilibrium between the two phases.

We cannot attain any particular separation better than this. It is important to remember that, in practice, we cannot attain equilibrium compositions. It will not be economically feasible. To achieve an equilibrium composition either we need very big equipment or we need a very long time of operation to achieve equilibrium.

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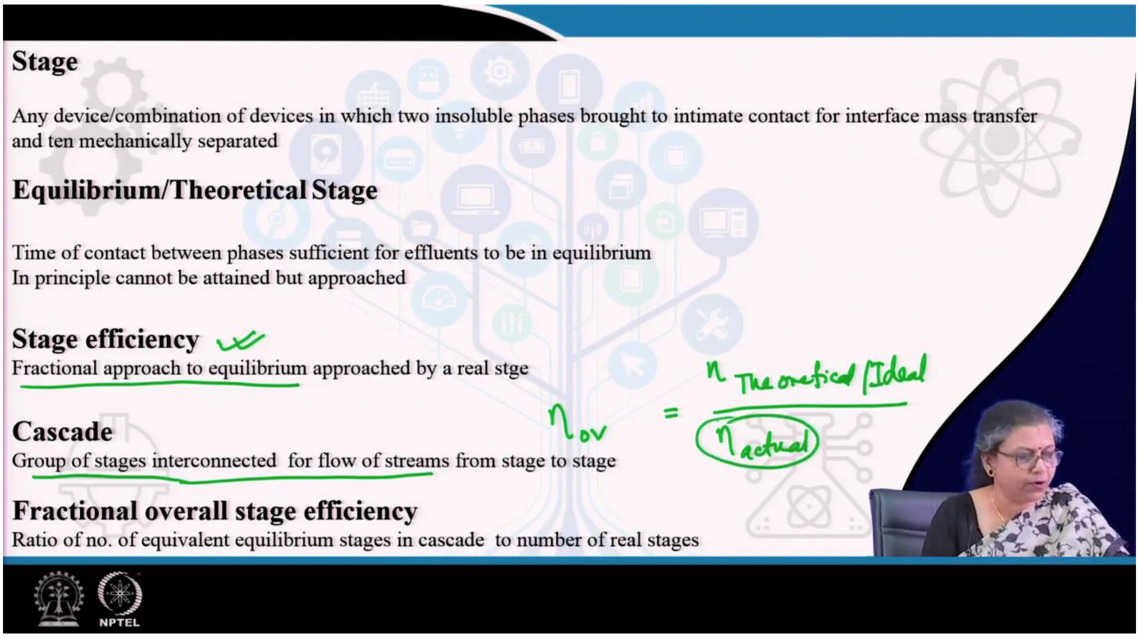

Stage

Any device/combination of devices in which two insoluble phases brought to intimate contact for interface mass transfer and ten mechanically separated

Equilibrium/Theoretical Stage

Time of contact between phases sufficient for effluents to be in equilibrium
In principle cannot be attained but approached

Stage efficiency ✓✓
Fractional approach to equilibrium approached by a real stge

Cascade
Group of stages interconnected for flow of streams from stage to stage

Fractional overall stage efficiency
Ratio of no. of equivalent equilibrium stages in cascade to number of real stages

$$\eta_{ov} = \frac{\eta_{\text{Theoretical/Ideal}}}{\boxed{\eta_{\text{actual}}}}$$

So, we can approach equilibrium but we cannot attain it. The fractional approach to equilibrium that we can achieve in an actual stage that is known as stage efficiency. We will be discussing more stage efficiency when we discuss the individual processes.

So, therefore, suppose by equilibrium considerations we know that for a feed of say benzene toluene comprising of say 50 percent or maybe 40 percent benzene 60 percent toluene. The maximum separation that we can get by the process of distillation is say 80 percent benzene, but we need 99 percent benzene.

So, how do we do it? We need to increase the number of stages or the number of contacts between the two phases and the group. As we increase the number of stages and we need to have some way by which the streams are flowing from one stage to other. The entire thing is usually housed in a tower or a column.

Therefore, the group of stages that are interconnected for the flow of streams from stage to stage is known as a cascade. So, for any particular separation, we need to find out the number of stages that are required in the cascade. How do we go about it?

We assume that all the stages in the cascade are ideal stages or equilibrium stages. In each particular stage when the two phases are contacted and the components got separated into the two phases as if they are in equilibrium with each other.

Again, you have to remember this never happens. So, what do we do? We find out the number of theoretical stages that are required to bring about some particulars separation. That is maybe denoted by n theoretical or n number of ideal stages. We know that definitely will be requiring more stages as compared to the ideal stages. So, therefore, the ratio of n ideal by n actual gives us the overall efficiency or stage efficiency of the process.

Whenever we design processes, the first thing that we do is that we are given some particular specifications. These specifications can be in terms of recovery or terms of purity. So, for that, we have to find out the number of stages that we require. For finding the number of stages we assume that for each stage, the effluent is in equilibrium conditions. Then, we assume some particular efficiency of each particular stage. We use the data on efficiency which are usually obtained from heuristics or they are available based on experience and using that we find out what will be the number of actual stages.

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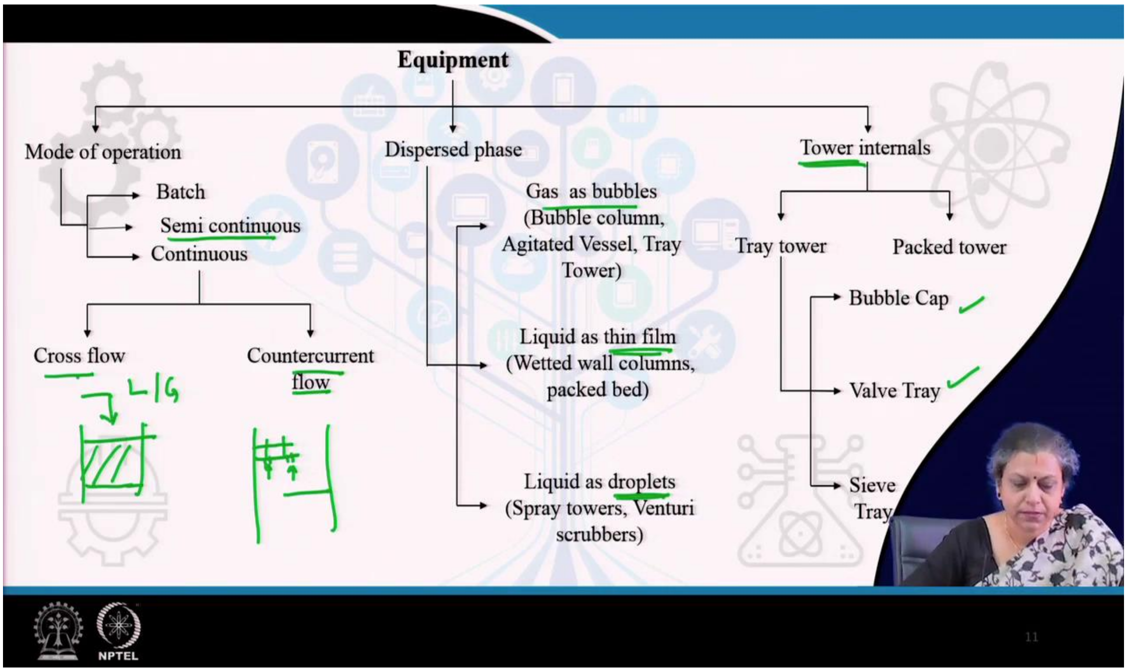

Equipment

Mode of operation
- Batch
- Semi continuous
- Continuous
  - Cross flow
  - Countercurrent flow

Dispersed phase
- Gas as bubbles (Bubble column, Agitated Vessel, Tray Tower)
- Liquid as thin film (Wetted wall columns, packed bed)
- Liquid as droplets (Spray towers, Venturi scrubbers)

Tower internals
- Tray tower
  - Bubble Cap ✓
  - Valve Tray ✓
  - Sieve Tray
- Packed tower

I have already mentioned, that all these stages are housed in a tower. In that tower to increase the mass transfer between the phases these towers, they are fitted with different sort of accessories. For example, we can have tray towers where within the tower there are a large number of trays which are fitted and in these particular trays either we can have some particular perforations through which the vapor can rise and flow through the liquid bubble through the liquid.

It can also happen that these perforations are fitted with some attachments etc. Namely, bubble caps and valve trays are common sorts of attachments. We will be discussing these. They are just to reduce the size of the bubbles and to enhance the mass transfer.

Now, in this case, I would like to mention one particular thing. See which phase should we disperse? We disperse the phases to increase the mass transfer, why does this happen? This happens because the diffusion path decreases and the interfacial area increases. So, quite naturally we would like to disperse that particular phase which is mass transfer controlling in any particular operation.

So, therefore, when the gas phase is mass transfer controlling we disperse the gas phase, when the liquid phase is mass transfer controlling we disperse the liquid phase. The liquid phase can be dispersed either as droplets or maybe they are broken down as thin films.

The different cascades of the flow can be mostly counter-current or it can also be crossflow. When we are having one phase as the solid phase often it happens that this solid is kept as a bed within the tower and either the gas phase or the liquid phase is made to flow through this, under which condition we say that the process is semi-continuous.

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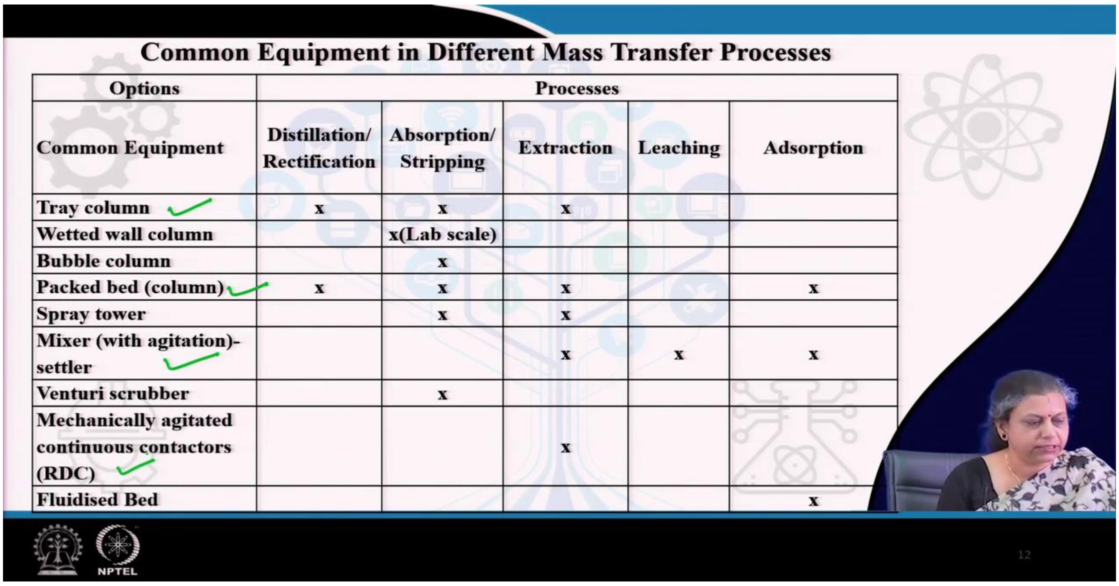

Common Equipment in Different Mass Transfer Processes

Options	Processes				
Common Equipment	Distillation/ Rectification	Absorption/ Stripping	Extraction	Leaching	Adsorption
Tray column ✓	x	x	x		
Wetted wall column		x(Lab scale)			
Bubble column		x			
Packed bed (column) ✓	x	x	x		x
Spray tower		x	x		
Mixer (with agitation)-settler ✓			x	x	x
Venturi scrubber		x			
Mechanically agitated continuous contactors (RDC) ✓			x		
Fluidised Bed					x

So, when we opt for which process, they have already been discussed in the introductory lecture. So, I will not be going through this. So, depending upon which phase should be dispersed and how many contacts we require. So, therefore, different processes mostly are performed on different types of equipment.

So, while we discussed the processes we will be primarily discussing about tray columns, packed beds, and while we discussed liquid extraction, we will be discussing regarding mixers-settlers, and rotating disc contactors. We find that these common equipments are used to enhance the mass transfer between the phases so that the operation can be achieved with a minimum number of stages.

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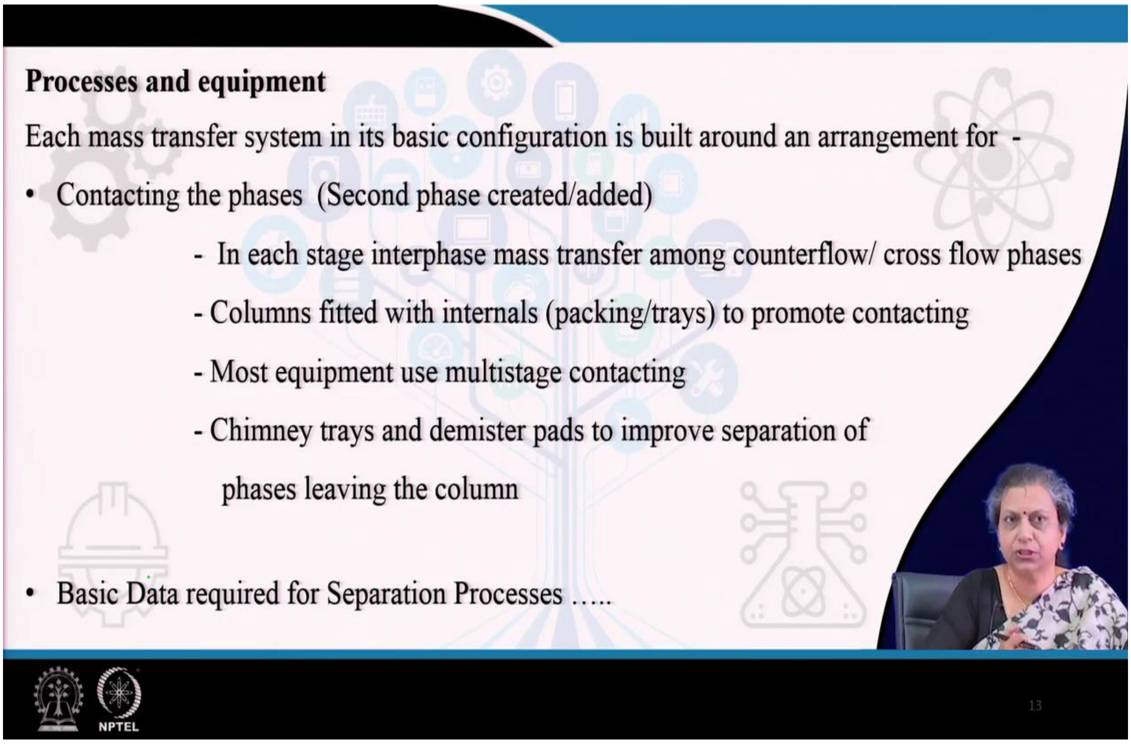

Processes and equipment

Each mass transfer system in its basic configuration is built around an arrangement for -

- Contacting the phases (Second phase created/added)
    - In each stage interphase mass transfer among counterflow/ cross flow phases
    - Columns fitted with internals (packing/trays) to promote contacting
    - Most equipment use multistage contacting
    - Chimney trays and demister pads to improve separation of phases leaving the column
- Basic Data required for Separation Processes …..

You should also remember that after the two phases are brought in contact and mass transfer occurs between two phases which have to be separated out. So, therefore, all those towers are also fitted with certain attachments, which would separate liquid droplets from the entering vapor or the gas stream. We have some demister arrangement; there will be some arrangement where the gas has to be separated from the liquid stream. We have vertex breakers and things like that.

So, when we design a column we have to keep this thing in mind as well. For designing our column we need to find out what should be the accessories, which are required for mixing or rather for intimate contact between the two phases and maximizing the mass transfer and also certain additional arrangements for separating the phases as completely as possible after the operation has happened.

But the first thing that we require for any separation processes for any interface mass transfer process is data on equilibrium. So, therefore, in the next class, we are going to discuss equilibrium or other phase equilibrium for all the processes that we have discussed in this class and after that, we will be taking up each process individually and going into the details of those. So, for today this much. Thank you very much.