Organic Chemical Technology
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Lecture - 02
Basic Unit Processes and Unit Operations of OCT

Welcome to the MOOCs course Organic Chemical Technology. The title of today's lecture is Basic Unit Processes and Unit Operations of Organic Chemical Ttechnology, right? So, we have seen in the previous lecture already that two third of the plant, approximately two third of plant is occupied by different types of unit operations and then connecting pipes etc., whereas the remaining are unit processes and other kind of accessories. So, then it is essential to understand a few basics about the unit operations as well as the unit processes also or a few basic unit operations and a few basic unit processes which are very much relevant to the course of organic chemical technology that we are going to discuss in this particular lecture. But the question is that why do we need to study them individually? like n number of unit operations are there and n number of unit processes are there. What is the point of studying them individually because they have a connection because we start with an example.

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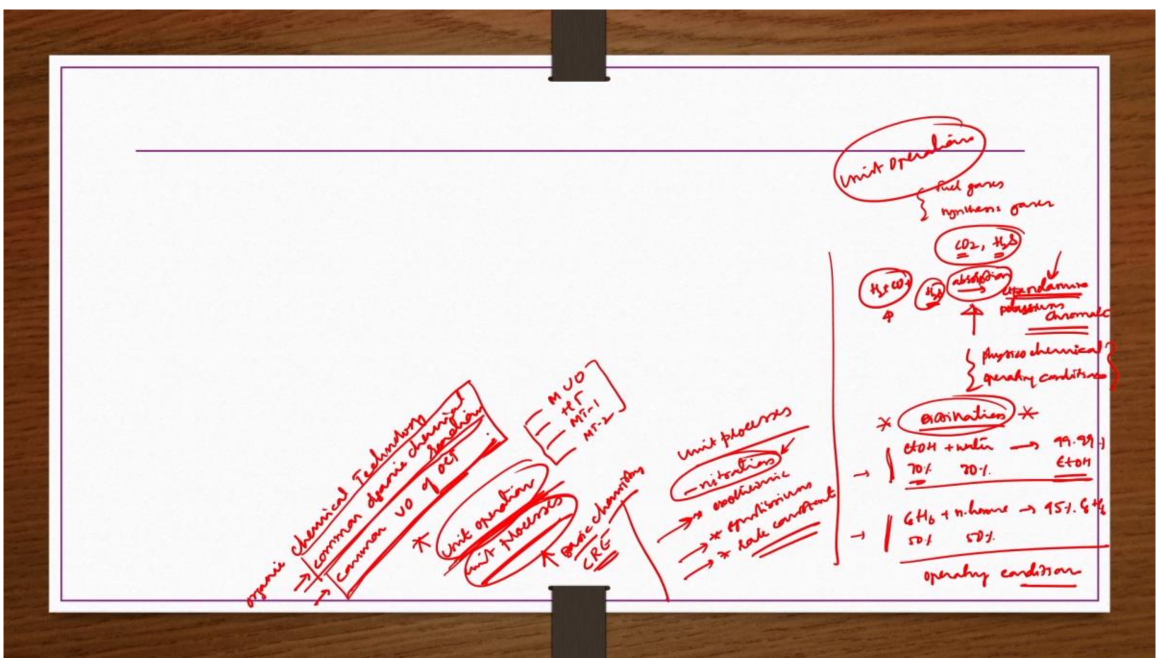

Let us say you are producing some kind of fuel gases or synthesis gases, right? For example, then in such kind of industrial gases productions what happens? You know

CO_2 or H_2S are found to be common impurities. In some cases, both of them may be present, right? So, we have to remove them without removing these impurities, we cannot use them for the required purpose. So, we cannot use these fuel gases or synthetic gases if these impurities are there. So, what are the options that in general we have like you know let us say H_2S is there.

You can absorb or absorption may take place, you can absorb this H_2S in a solution, ethanol amine solution or potassium chromate solution, different kind of solutions are possible, right? So, let us say whatever H_2 plus CO plus H_2S there, so then what happens? The solvent has to be selectively selected whether it is ethanol amine or potassium chromate solution or any other kind of solution so that in that solvent only H_2S will get absorbed whereas this H_2 plus CO will not. So that you know once this H_2S is being absorbed and then remaining gas is only having H_2 plus CO pure gas that you can use for your applications. So, whether are you using ethanol amine or potassium chromate to get H_2S absorbed, whatever the principles of absorption are there, they are not going to change. They are not going to change, they are going to be same, only that whatever the physicochemical properties of the system you have taken, right? And then operating conditions at which most amount of absorption can take place, those things you know may be changing, but the principles of absorption will not change. Likewise, if you take a distillation for example, right? In the distillation what you are trying to do? In general, let us say you have ethanol plus water solution, right? You wanted to purify ethanol to the 99.99 percent. Earlier it was only 70 percent ethanol, remaining 30 percent was water. So, if you do the distillation it is possible that you can get this much of purity ethanol, right? Now, if you have a benzene or n-hexane mixture, mixture of benzene and n-hexane if you have and then you wanted to purify again, let us say initially they are 50-50. Now you wanted to make most of the benzene like almost 95 percent benzene you wanted to get pure. So, it is possible. So, whether this system are you taking or this system you are taking, but if you are using distillation, the principles of distillations are not going to change. Only thing that the again here again the physicochemical properties of the system whether ethanol, water, mixture or individual component and then similarly, in this case benzene and n-hexane their properties or their mixture properties are going to change in addition to the operating conditions. So, the point of discussion of these 2 examples is that let us say if you have a requirement of distillation, right? So then it is not going to be a different process for your new system, it is going to be the same thing. Only thing that you know accordingly you have to select the operating conditions, etc. So, what you can do? You can study distillation as a separate you know chapter or a separate subject rather than you know studying individually wherever it is occurring, because the principles are not changing, same is true for the absorption.

So, these are the few examples for the unit operations, right? Now, if you take unit processes, so let us say if you take the nitration reaction, then this reaction is always almost exothermic. So, the concern equilibrium constants or equilibrium rate constants, etc., they are not going to change very much from one nitration reaction to the other nitration reaction if the nature of the nitration is similar, right? So, what I mean to say? Let us say if you have a knowledge of nitration reaction and then you know that it is exothermic reaction and then you know that you know these rate constants, equilibrium rate expressions, etc., how to derive and all those things, such kind of basic information, basic knowledge you can use for any new system where again nitration is taking place. So, that is also possible in general for the most of the unit processes also.

Considering these examples, what we can realize that it is better to have a separate course or separate courses for unit operations and then unit processes because these unit operations and then unit processes, unit operation mostly majority of the unit operations may be there in most of the chemical plants. Unit processes, some specific reactions may be there in given specific kind of products, etc., right? So, considering these things, if we can individually study in detail, then that is going to be very much beneficial. Let us say unit operations, most of the unit operations you may be studying in mechanical unit operations course, heat transfer course and then mass transfer course, mass transfer 1, mass transfer 2 courses, something like this. In these courses, most of the unit operations you would be covering, right? Unit processes, most of the unit processes in general you study in basic chemistry, whether it is in organic chemistry or organic chemistry and then some part of this unit processes you also study in chemical reaction engineering courses along with their kinetics, etc., those kinds of things. But however, since we are talking about technology, especially chemical technology and then this chemical technology also about organic chemical technology, it is essential to know some common organic chemical reactions or unit processes and then common unit operations of organic chemical technology. So, this is the requirement actually. So, you cannot study in detail about each of the unit operation and then each of the unit process in this particular course, but what we do, we have a kind of basic information, basic knowledge so that you do not feel like you do not know anything about a certain unit operation when it is occurring or when you see it in a kind of a flow sheet, then in a flow sheet when we are going to discuss about specific type of organic chemical productions. Other way what I mean to say that let us say some of the unit operation that we are going to discuss in this lecture, you may be seeing that some of these unit operations are being utilized or being used in production of certain kind of organic chemicals in the due course of the course.

In upcoming week lectures of this course, you can realize that some of the or maybe almost all of the unit operations may be involved in different plants if not in one single plant, okay? So, with that background, we start about a little introduction about the unit operations and unit processes. Then we discuss a few examples of unit processes as well as a few common unit operations that we come across in general in organic chemical industries. Chemical plants consist of two-third of unit operations approximately and

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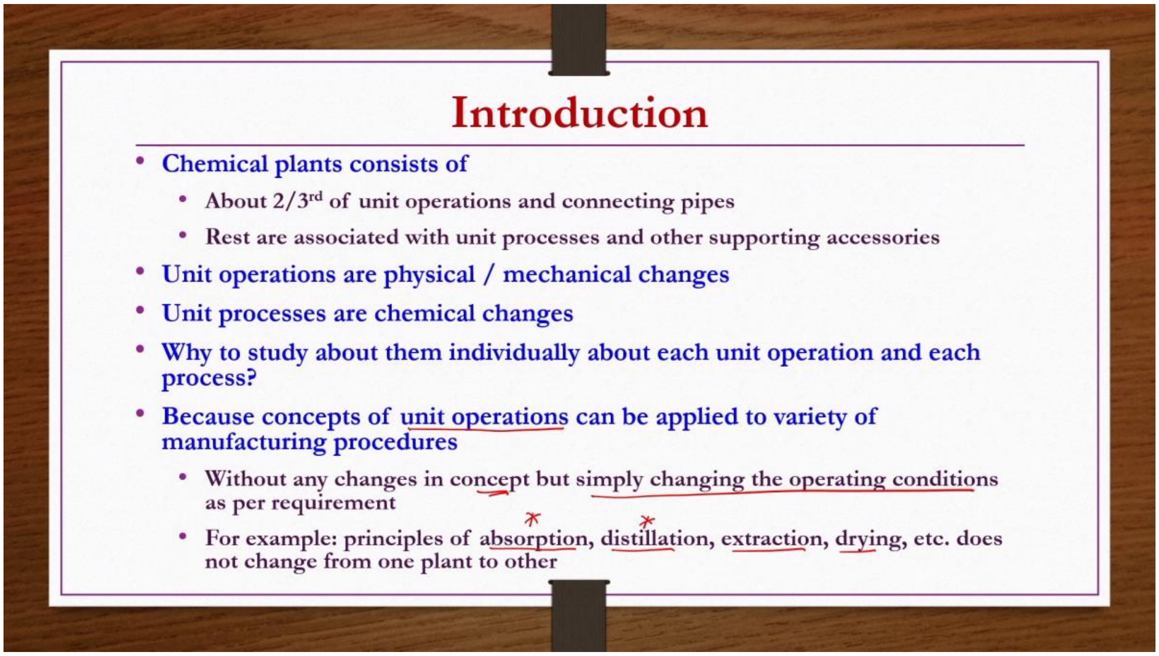

connecting pipes, whereas the rest of the things are associated with the unit processes and other supporting accessories etc. We already know that unit operations are physical or mechanical changes, whereas the unit process or chemical changes. Then why to study about them individually about each unit operation and then each process because concepts of unit operations can be applied to variety of manufacturing processes without changing any basic concepts, without any changes in concept, but simply changing the operating conditions as per the requirement of a plant, okay? That means distillation principles are going to be same whether it is going to be utilized in plant 1 or plant 2 or plant 3, okay? For example, principles of absorption, distillation, extraction, drying, etc. does not change from one plant to the other plant. Absorption example, distillation example I just now explained, okay?

Now, coming to the unit processes, there exist n number of chemical reactions especially in organic chemistry, right? And these reactions are going to be very useful for organic chemical technology in general, okay? So, chemical engineers may apply chemical reaction performance knowledge of literature to new type of chemical produced from one or more-unit processes. For example, nitration reactions are almost always exothermic and all of the physical and chemical principles of equilibrium and reaction rates are similar as long as the reaction is the nitration type of reaction. And then further depending on severity of operation conditions, selection of construction materials and equipment for unit processes should also be categorized. If you see one example here, let us say if you have liquid phase nitration reaction carried out in well agitated reactor with provision for heat removal as well, then the material of construction for this kind of liquid phase nitration reaction is cast iron that is sufficient. But if you go high temperature and then high pressure reactions such as hydrodeoxygenation, then if the reactor is made up of such kind of cast iron that is not going to sustain such severe conditions, okay?

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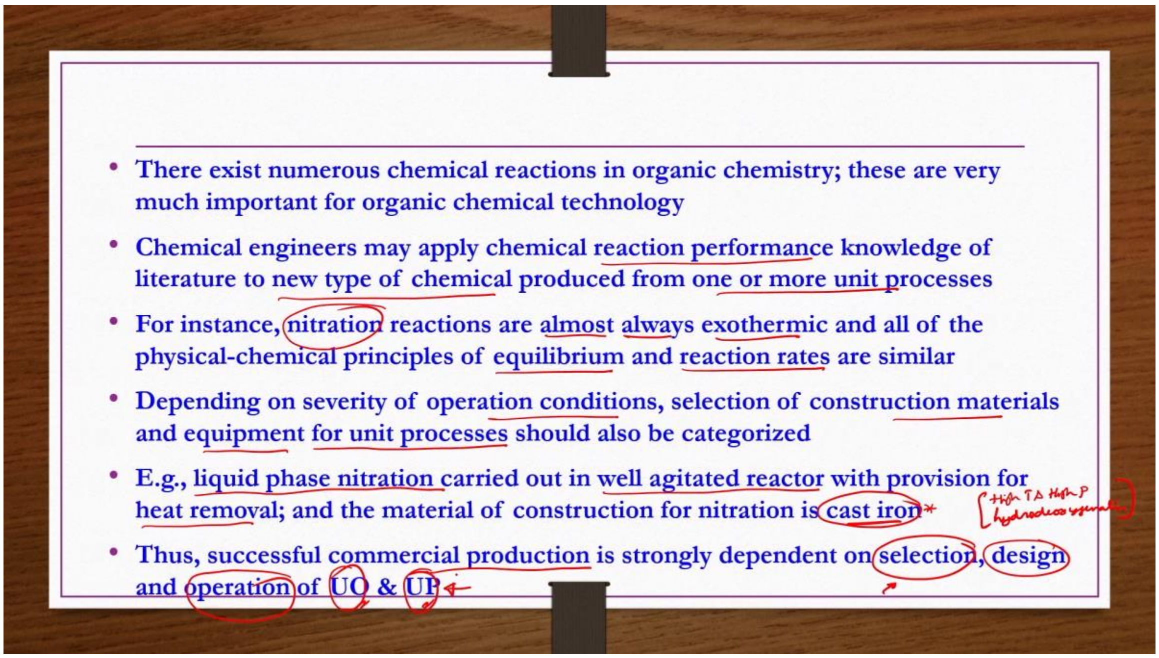

So, this is also very essential. Thus, successful commercial production is strongly dependent on the selection, design and operation of different types of unit operations and then unit processes, okay? Selection is also important. We are going to see a few examples in the next lecture. You know for a given organic chemical production, there may be dozens of processes available, reaction types are available. You have to select the most appropriate one which is most profitable along with the safety and then pollution concerns as well, okay? And then design and operation of those unit operations and unit processes also very much essential for the understanding purpose.

So, but however, this part is not coming in our particular course of organic chemical technology. So, we will see a list of such unit operation and unit processes and we see basic way how they are working, how they are important to the given organic chemical technology course. So, let us start with unit processes of organic chemical technology. Here mostly we are discussing about organic chemical processes only. Alkylation, let us say alkylation, alkyl as the name indicate, alkanes. From the alkanes if you remove 1 H plus or proton, then whatever the radical is remaining that is known as the alkyl radical. Let us say from the methane if you remove H plus, whatever CH3 minus is there that is nothing but your methyl radical. Like that alkylation is nothing but addition of alkyl radical with sidechain final product. For example, you have 1 butene and then isobutene. 1 butene and the isobutene you are having.

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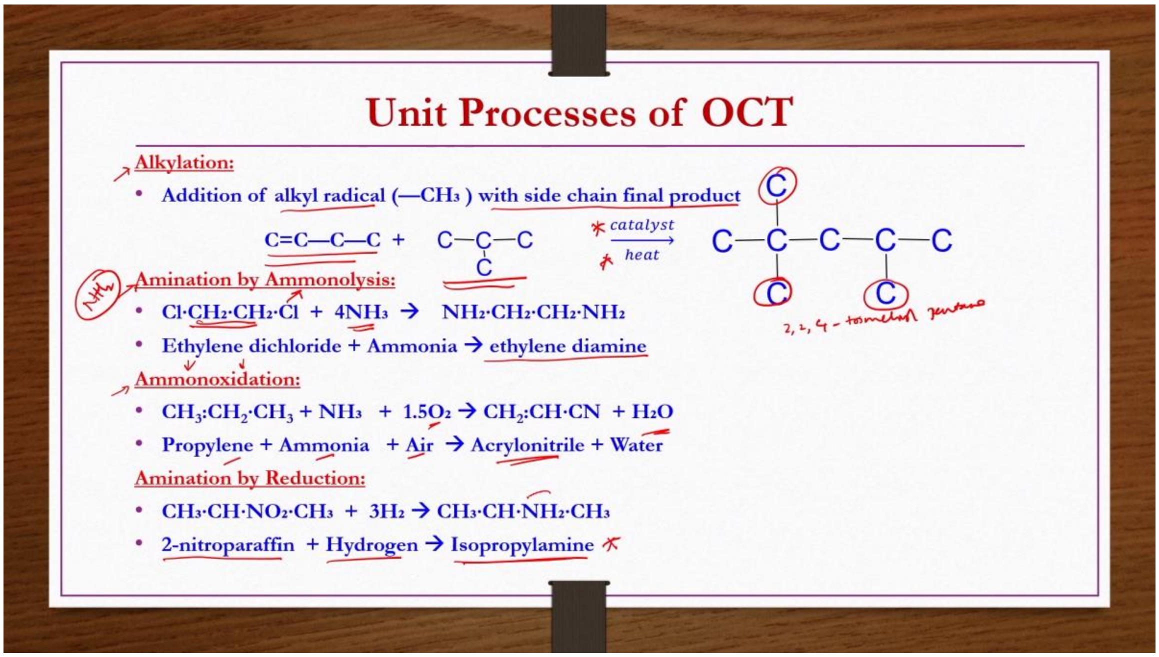

If you take the mixture and then heat it in the presence of catalyst, then you may be getting 2,2,4 trimethyltentane. So, for the second carbon, 1 methyl, another methyl, so 2, 2 and then for the fourth carbon again another methyl radical is there, so 224 trimethyltentane you are getting. What are these suitable catalysts, what temperature should they be heated, etc., we are not going into the details. Let us say if the size of this component increases, then these catalysts and then operating conditions will change slightly or they may change significantly also.

We are not going into the details of such operating conditions like temperature, pressure and then catalyst, etc., we are seeing only a few basic organic chemical processes only. Next one is amination by ammonolysis. Amination by the term amination that means you are attaching NH2 minus functional to one organic molecule. How are you doing? by using ammonia. Since you are using ammonia for this amination reaction, this amination reaction whatever is there that is called as ammonolysis. If you take a reaction here, what you have ethylene, you have ethylene dichloride and then ammonia, when these 2 are reacting, you are getting ethylene diamine, okay? Now, we take ammonoxidation. Since reaction is having ammonia and oxidation both, then this reaction is known as ammonoxidation. For example, you have here propylene and then ammonia plus air or oxygen to get acrylonitrile plus water, okay? This amination may also take place by reduction as well, right? So, amination by reduction. Reduction best way of, best reduction agent is nothing but H2, right? So, let us say if you take these 2 nitroparaffin and then react with hydrogen, you get isopropyl amine as a product. So here NH2.

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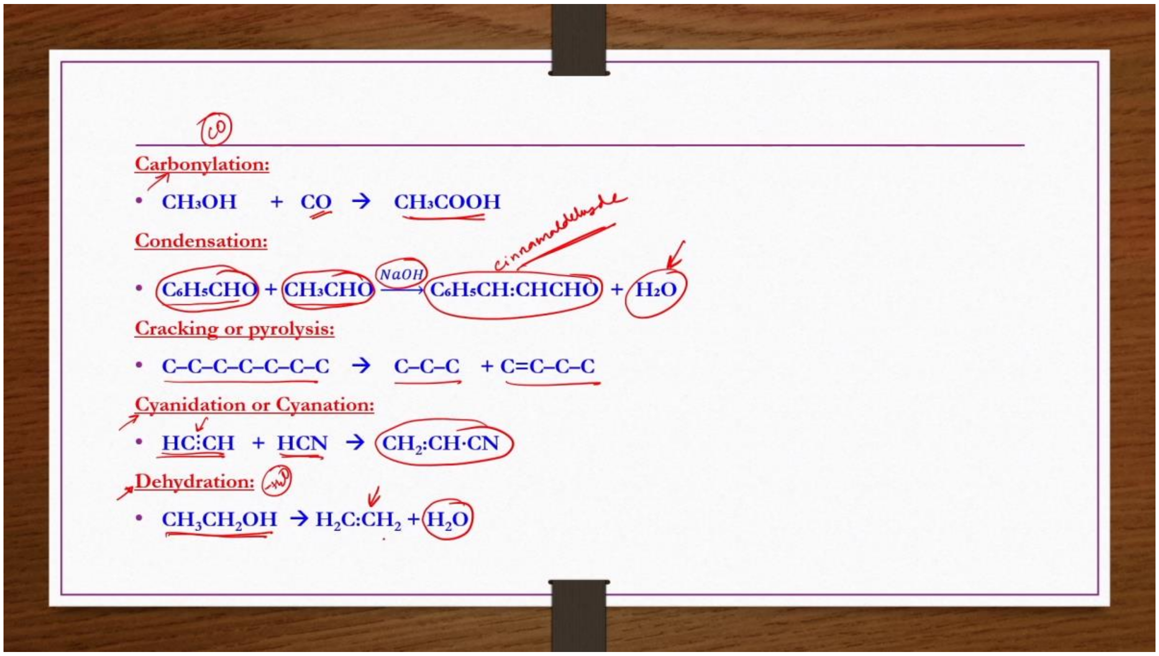

Next is carbonylation. Carbonylation that means CO is involved in the reaction. How it is involved? Let us say you have methanol reacting with carbon monoxide, then you are getting acetic acid, okay? Then condensation reaction. Let us say you have benzaldehyde and acetaldehyde and then if you are reacting them together in the presence of NaOH, then you get cinnamaldehyde, right? Bigger molecule you are forming. Two smaller molecules are reacting together to form a bigger molecule and releasing water that is condensation. So such kind of reactions are also common in polymer industries. We see polymer condensation example as well. Cracking or pyrolysis, whereas this cracking or pyrolysis is reverse where you have a bigger size molecule and then you supply energy in the absence of oxygen or in the presence of inert atmosphere if you do it, then what happens that bigger molecule break into the smaller molecules. Something like here, now here 7 carbon atoms are there, so then you are getting 3 here and then 4 here, propane and then butylene, okay? Cyanidation or cyanation, so this is nothing but as the name indicates cyanide functional group is being attached to the organic molecule, right? For example, if you take acetylene, right? Acetylene triple band is there and then if you react it with hydrogen cyanide, then you will get acrylonitrile, this one, okay? Dehydration by the indication of the name, you know from the molecule you are trying to remove water molecule, from the organic molecule you are trying to remove H2O, so then that reaction is known as the dehydration reaction. Let us say you have ethyl alcohol, from the ethyl alcohol if you take off the water, then you will get ethylene. Hydration reaction if you take, it is a reverse of this one, you take ethylene and then react with water, then you get ethanol, so that would be hydration reaction that is water is being added up, okay? Or water is allowed to react with the molecule to form another molecule, whereas in dehydration from one molecule H2O is being removed to get some other new molecule, right?

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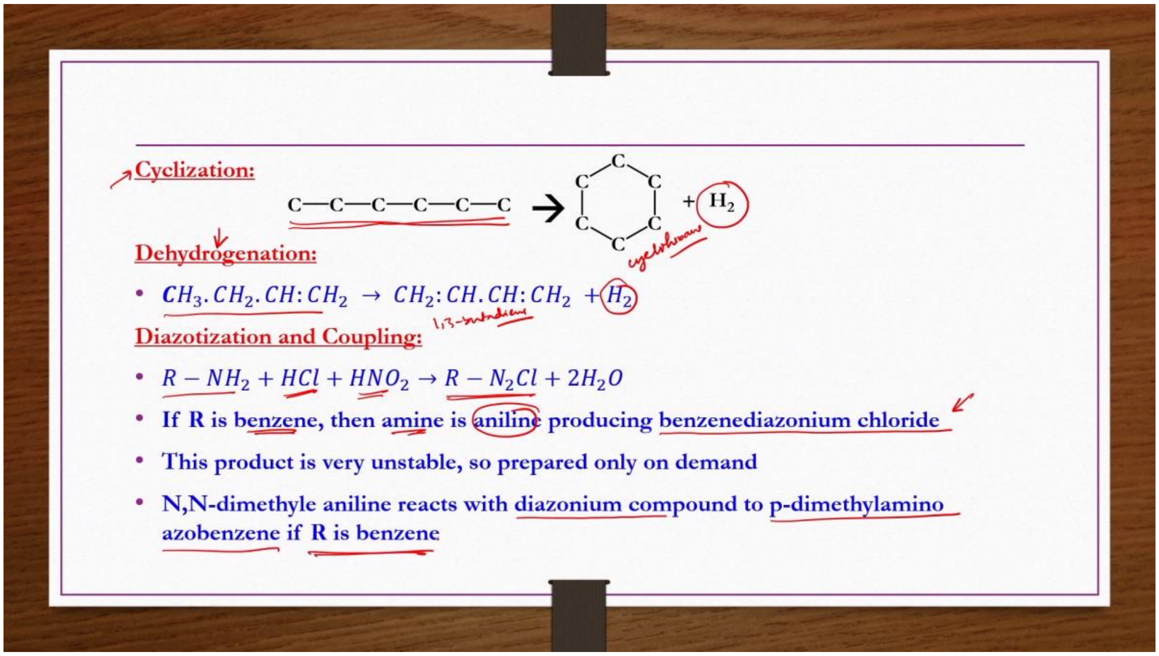

Next reaction is cyclization. Cyclization as the name indicates, you may be having a linear molecule and then some kind of reaction undergoes as per the required operating condition and catalyst, etc. Then what you get? You can get a cyclic molecule, then such kind of reactions are known as the cyclization. For example, you have n-hexane and then when it undergoes a reaction under suitable conditions of temperature, pressure and catalyst, H2 is being released and then cyclohexane is produced from n-hexane which is linear, you are getting cyclohexane by releasing H2. So this reaction since cyclic compound is formed from a linear compound, so it is known as the cyclization reaction. Next is dehydrogenation reaction. Hydrogenation that means adding hydrogen, dehydrogenation in the sense removing the hydrogen. For example, from this molecule if you remove the hydrogen, you get 1, 3 butadiene as a product. Next is di-azotization and coupling reaction. So here let us say you have 1 amine and then it is reacting with hydrochloric acid and nitrous oxide, then you get 1 azonium compound along with the water. Let us say for example, if R is benzene, then RNH2 amine whatever is there that is nothing but aniline and then it reacts with HCl and HNO2 to give benzene di-azonium chloride. Such kind of components are having very rare market, so these kinds of components are produced on demand in general because they are unstable as well. Similarly, N,N-dimethyl aniline reacts with di-azonium compound to P or para-dimethyl amino-azobenzene if R is benzene. So these are some of the examples of di-azotization and coupling reactions.

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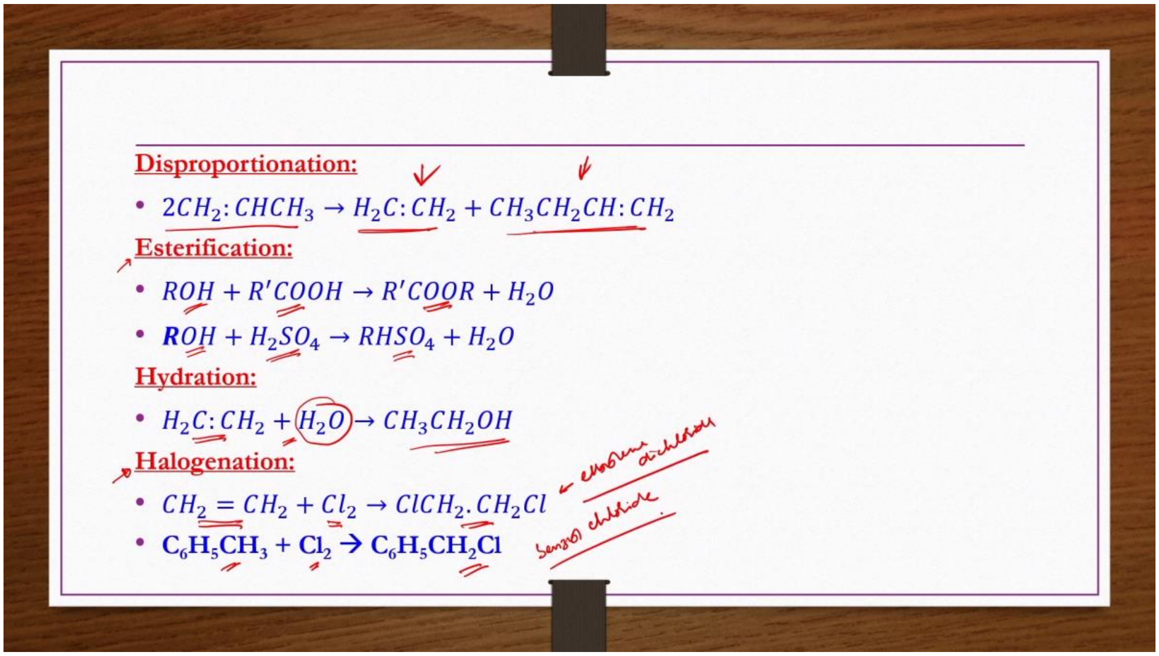

Next one is disproportion reaction. In such kind of reactions what happens in general, 2 molecules of same component reacting to give one smaller and one bigger molecule as a product. For example, if you have 2 moles of propylene, it is undergoing some kind of decomposition reaction to give ethylene as well as butylene. So now here ethylene 2 carbons and here butylene 4 carbons and with the double bonds are there. So a kind of disproportion reaction is taking place. Esterification, as the name indicates, esters are being formed. For example, one alcohol, one carboxylic acid group reacts together to give an ester by releasing water or alcohol may be reacting with some other common acids like sulfuric acid, etc., to give esters and then water, okay? Hydration, as name indicate, hydration means adding the water. Let us say you have ethylene if you add water and then do the reaction under suitable temperature and pressure and then catalyst conditions, you may get ethanol, right? Halogenation as the name indicates, halogens are being attached to organic molecules. Let us say if you have again ethylene and then if you react it with chlorine gas, then you may get dichloroethylene or if you have toluene and then react with chlorine gas, then you will get benzyl chloride. This is ethylene dichloride, okay? So these are the two examples of halogenation reactions.

Now hydroformylation, by title, by name indicates hydro that means hydrogen is involved and formulation that CO is involved. So that means if you take one organic component, react with CO and then H2, then you may get you know aldehyde like this, okay? That is using hydrogen and then CO, you are trying to get aldehyde and then such kind of reactions are known as the hydroformylation reactions. Hydrogenation reaction, as the name indicate, hydrogen is being added up to get a new product by reacting hydrogen with some other organic. Let us say R double bond R prime, if you react with hydrogen, you get RHH R prime. Hydrolysis here, H2O is being added to the halogenated components. Let us say C6H5Cl that is chlorobenzene, it is chlorobenzene.

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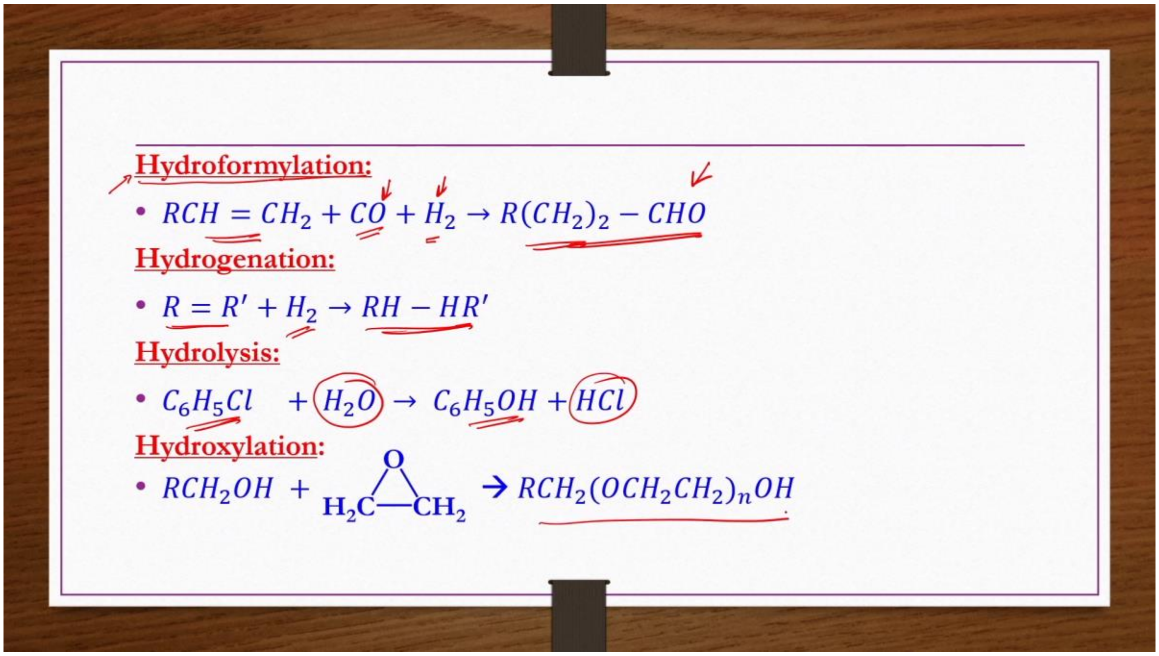

Chlorobenzene if you react with water, then you get phenol and then HCl. Hydrogen, let us say you have one alcohol and then reacting with ethylene oxide, so then you are forming a bigger molecule like this, alcoholic molecule.

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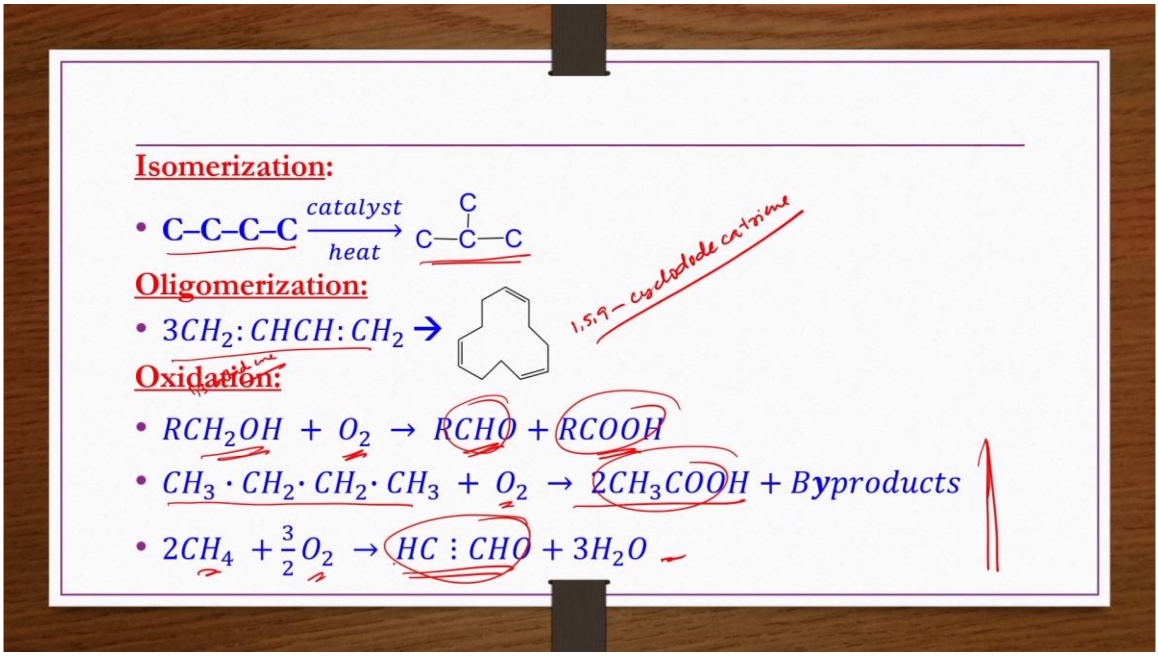

Isomerization, so isomers formation takes place in this reaction. Let us say you have butane and then if you take suitable heat and catalyst and then you can get isobutene as a product. Oligomerization, for example, you have this component which is nothing but 1, 3 butadiene. Under suitable conditions and catalyst, you get this kind of component that is 1, 3, 5 butadiene, butadiene, butadiene, butadiene, butadiene, butadiene, butadiene, butadiene, such kind of oligomers formation takes place. Oxidation is simply reacting with the oxygen or air. So let us say if you take alcohol, react with oxygen, so then you get aldehyde as well as the carboxylic acids. Another example is given here. You have here butane reacting with oxygen to give 2CH3COOH and byproducts as well. Then methane, if you do the oxidation, you get formaldehyde and then water. So in this oxidation reaction, either aldehydes or carboxylic acids are forming. So their basic principles are their equilibrium, rate expression, rate constants, etc., nature of the reaction whether exothermic or endothermic, more or less they are going to be similar. Only thing that from one molecule to the other molecule when you go, the energies levels may be changing, etc., those kinds of things may only be there.

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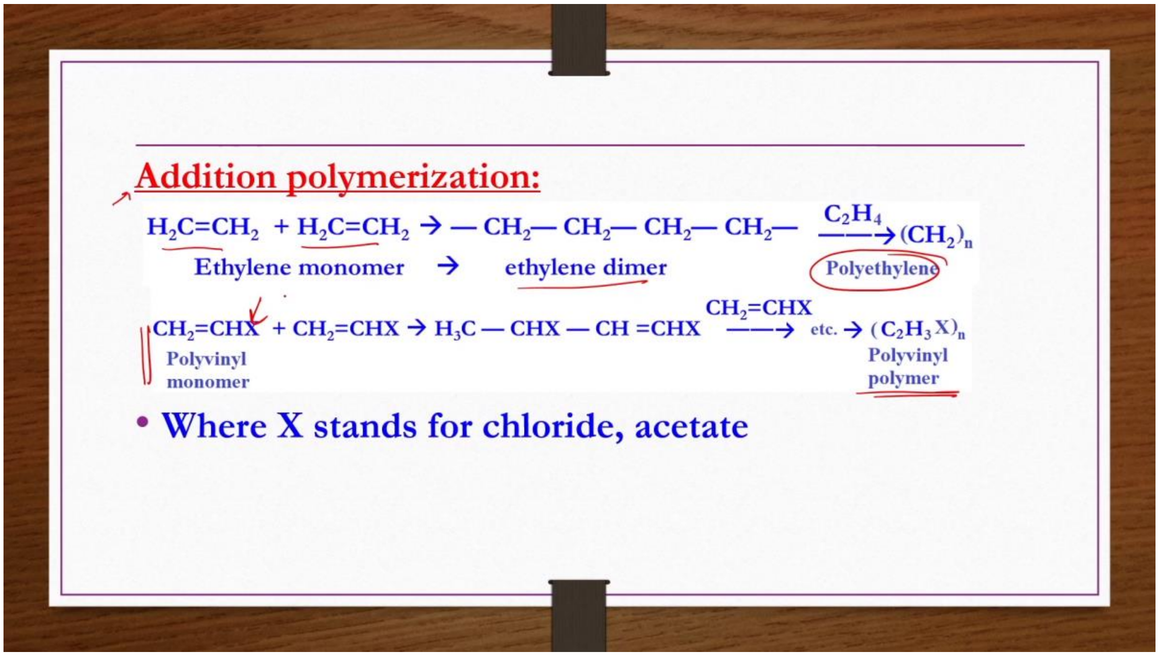

Addition polymerization. Addition as the name indicates that is n number of monomers are being added up to form a base bigger size polymer which is having entirely different physical and chemical properties compared to the monomers. For example, ethylene you take, 2 moles of ethylene you take, then ethylene dimer forms. Like that so many ethylene monomers you add, then you get polyethylene, right? Likewise, polyvinyl monomers, n number of such when you react together, you get polyvinyl polymers, okay? So in this reaction, this x may be chloride or acetate functional.

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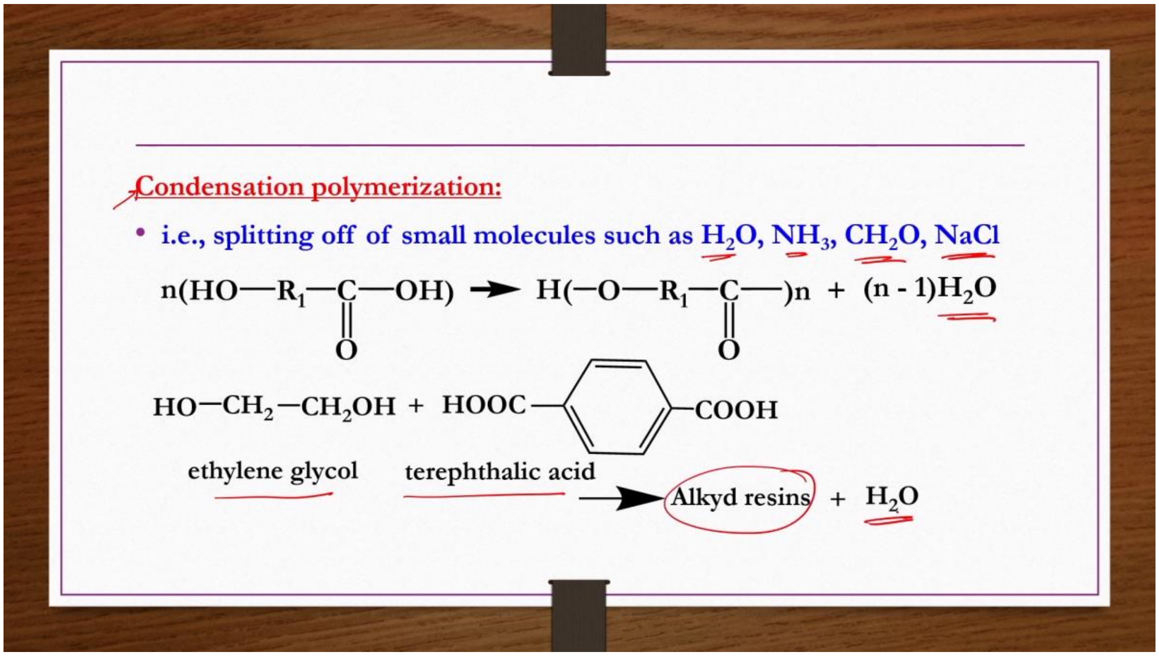

Condensation polymerization as we already seen one example for the condensation reaction. Condensation reaction in the sense smaller molecules will be added up together to form a bigger molecule by releasing water. So here splitting of small molecules such as water, ammonia, formaldehyde and then NaCl, etc., takes place. For example, this is one reaction, now water is being released here and then ethylene glycol, tertelic acid react together, you get alkyd resins and then water is being released.
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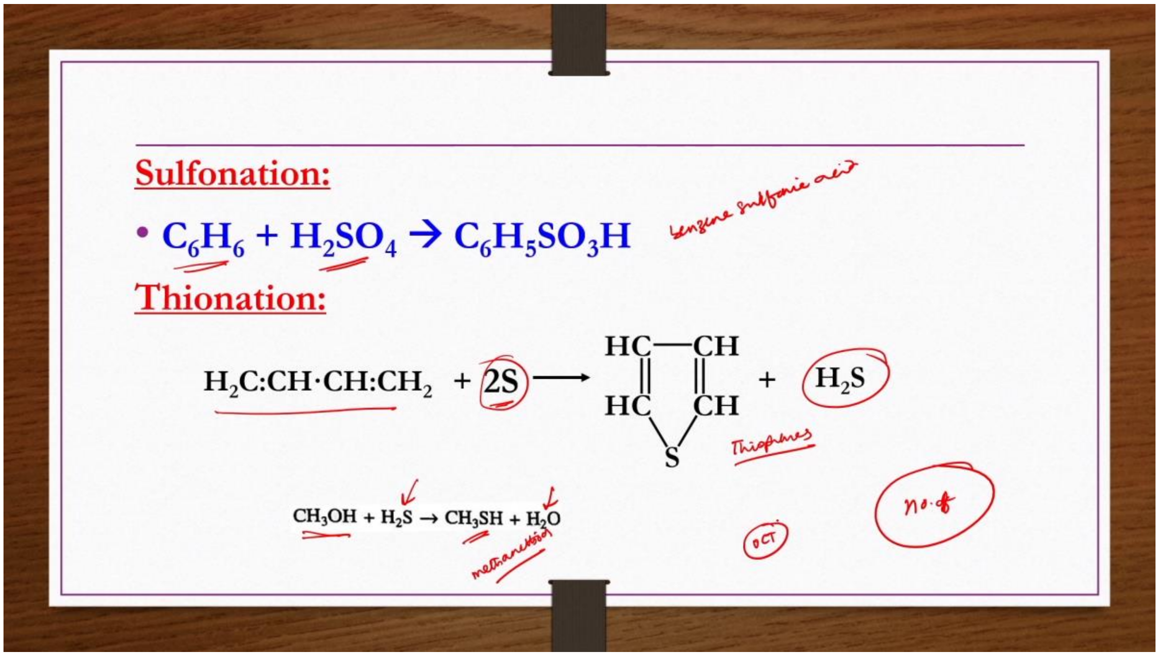

Next is sulfonation. For example, you have benzene reacting with sulfuric acid, that sulfonation in the sense sulfonate group is being attached to organic molecules. So now benzene and then H2SO4 when they react together, you get benzene sulfonic acid, right? Likewise, thionation is another type of unit process. Here let us say 1,3-butadiene if you react with elemental sulfur, then you get thiophenes along with H2S. So this thionation reactions either they take place using elemental sulfur or they react with H2S to get some kind of products like this. For example, another one is methanol if you react with H2S, you get methanethiol and then water is being released. Like that if you keep on listing, huge number of organic reactions are there which we may not even complete in purely organic chemistry courses. So these are a few basic information that may be required from the course content point of view. So I have presented a few of them.

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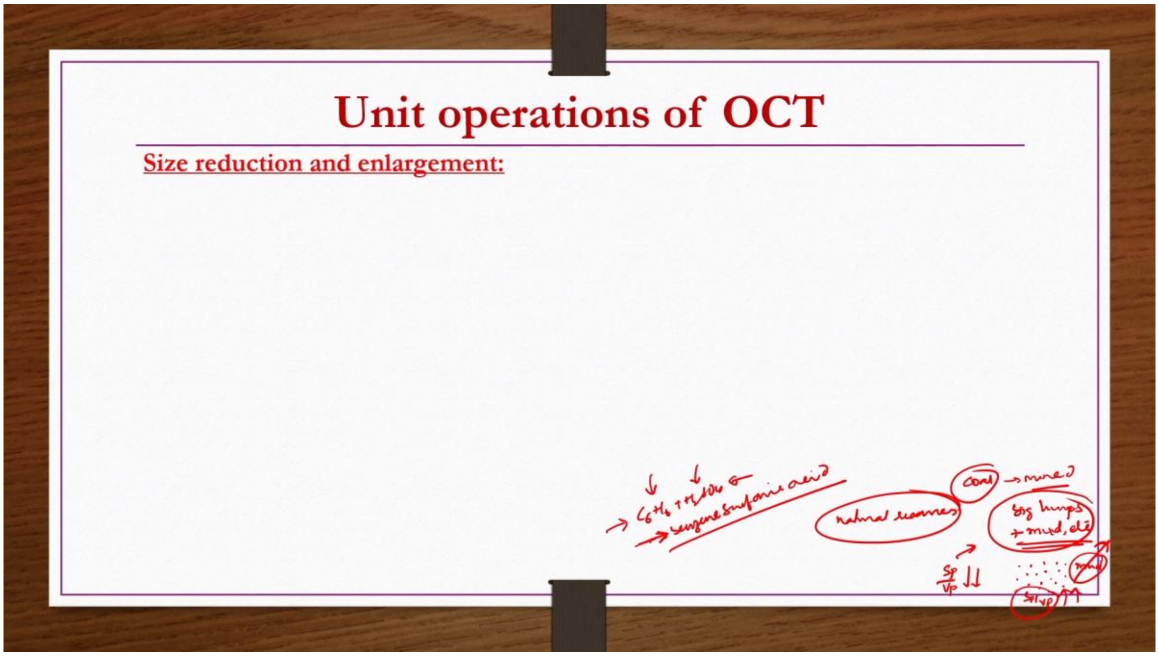

Now likewise, we will discuss now about unit operations. Unit operations are physical changes. So physical changes takes place from the mining point or collecting the raw material from the natural resources onwards to the processing them so that those raw materials become suitable to undergo reactions and then after the reaction purifying the products and all those different stages different types of unit operations are involved. Again n number of unit operations are there, we may not able to see in detail of each of them, but we see a few of them and then also for those few of them, we see a few basics, you know, what for they are used and then what is the way that these things are working those kind of minimum information is sufficient from this course point of view. Details of such unit operations anyway you will be learning in other courses. Unit operations of organic chemical technology. In fact, the unit operations that we are going to discuss now, they are not only suitable for organic chemical technology, but they are also suitable for inorganic chemical technology as well. So let us start with size reduction and enlargement. Size reduction that means reduction of the size is required.

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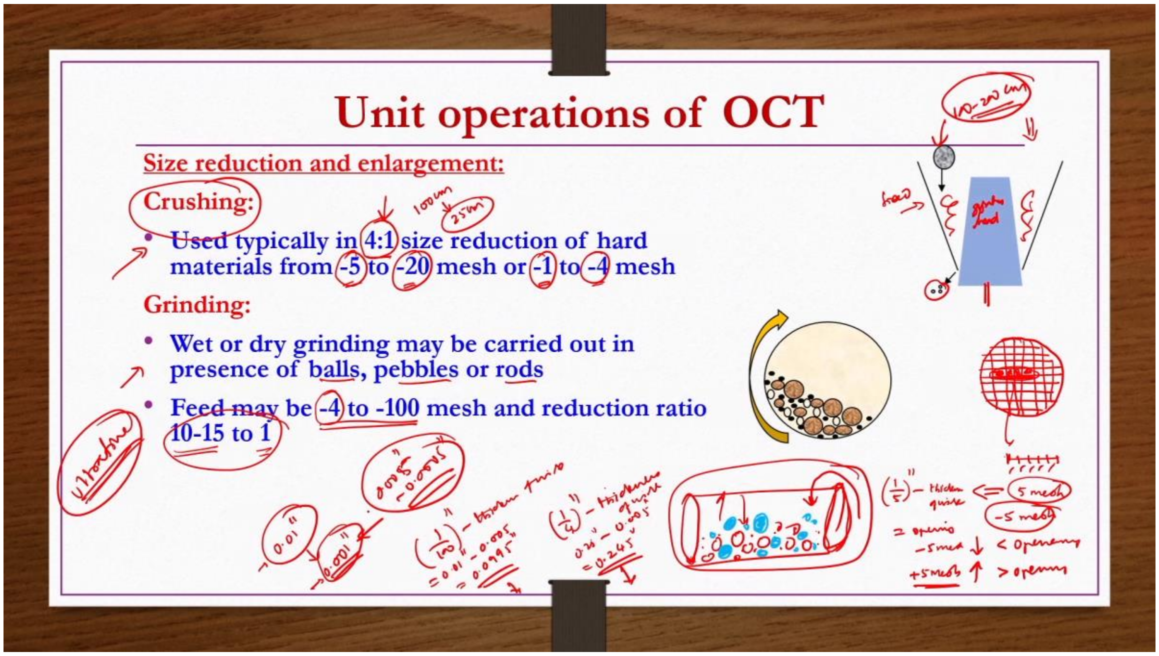

Let us say you are doing you know coal combustion. So but this coal when it is mined big lumps would be there and then mud etc other impurities may be there. So this big lumps as it is along with the impurities if you take because of the small Sp by Vp that is specific surface area, it is very small because of that one, the effective reaction would not be taking place. Also this mud etc is there that is also not going to be washed off or taken off you know that is going to be interfering the reaction subsequently that we are going to do the combustion reaction. So, the process is going to be least efficient if you take as it is. So, what you do if you crush them and then you take smaller particles carbon particles like this after crushing like this or size reduction I mean to say crushing in the sense here. Then what happens whatever the mud etc whatever is there that can be washed out and then dry these particles carbon particles after washing out the mud etc those kinds of impurities. Then dried carbon particles you know since they are small in size their Sp by Vp is going to be very high. So the effective reaction or the effective transport process whatever is supposed to be taking place and the subsequent level that is going to be very high very efficient. So that is the reason this size reduction is very much essential for almost all you know plant which is starting from the natural resources. Let us say just now we have seen C6H6 plus H2SO4 giving rise to benzene sulphonic acid you are trying to produce this benzene sulphonic acid. So, benzene pure you got from the petroleum industries H2SO4 you got purely from sulphuric acid plant. So, you do not need to do all this size reduction etc this kind of thing. In fact, this example itself is not appropriate because these are the liquids anyway.

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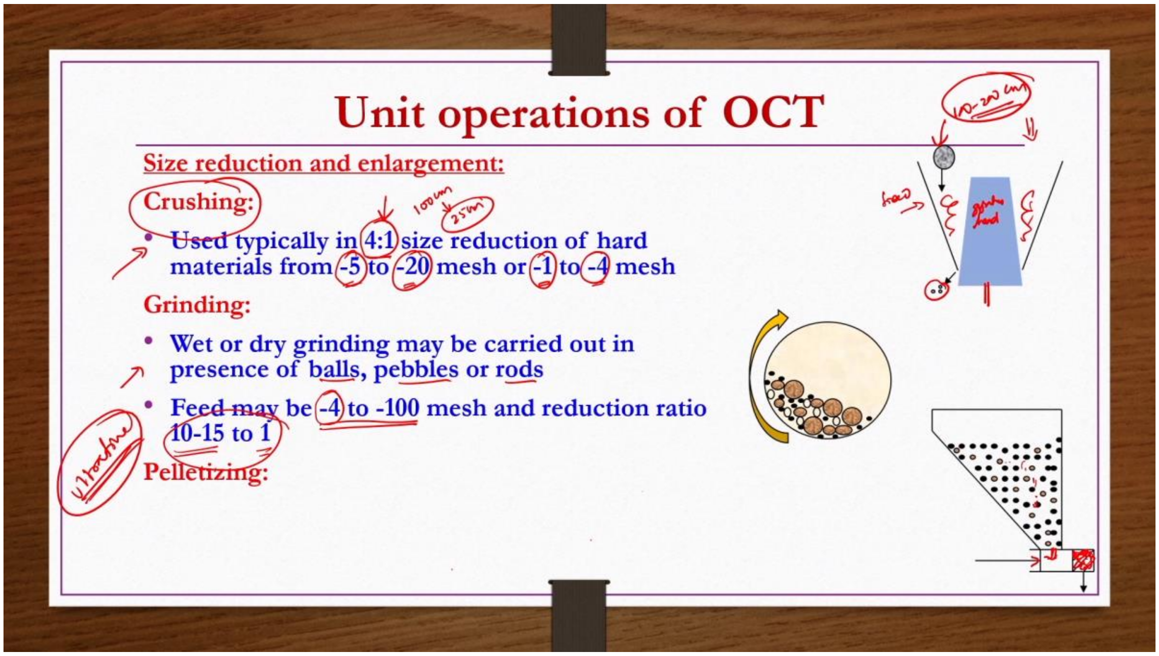

So, if you have the process to raw materials, then you do not need to go through all the size reduction washing purification kind of process. But if your basic raw material is a natural resource, then you have to do all these things. So in order to demonstrate the importance of size reduction we have taken an example like that there may be n number of applications where size reduction may be important. So, for size reduction different types of processes are there crushing, grinding, ultra-fine grinding and then cutting etc this kind of operations are there. So under each category of this size reduction equipments or processes again different kind of you know details are there.

So, we are not going into detail of each of these aspects anyway it is out of the scope of the course. So, let us see crushing. Crushing is a coarse crushing let us say whatever the natural resource ore that you get or the basic natural raw material that you get in big lumps which may be having you know 100 to 200-centimeter size average size. Actually, they are not in spherical size exactly but there will be very irregular size. So even though they are in very irregular size there are certain kind of methods to obtain average size of the particle. So let us say that lumps are having such big size. So obviously you cannot take them into the reactor for the reaction also they are carrying some kind of impurities. So then you do this crushing. So by doing this crushing this 100 to 200 centimeter size particles may be reduced to something like you know 10 to 20 centimeters or even smaller something like that. But after the size reduction also majority of the particles are having bigger size that is the reason crushing operation is known as the coarse size reduction operation. So here one gyratory crusher is shown as an example. Here we have a fixed head and then one gyrating head here. So the material whatever to be size reduced that would be taken in the intervening space between these two and then when this gyrates here and there so this bigger size particles would be size reduced and the smaller ones would be forming. So this is coarse reduction only. So these are used typically in 4 is to 1 size reduction of hard materials from minus 5 to minus 20 mesh or minus 1 to minus 4 mesh. What do you mean by 4 is to 1 ratio? Let us say if you have the feed material 100 centimeters average size then the product average size would be approximately 25 centimeters. What do you mean by minus 5 and then minus 20 or minus 1 minus 4 mesh? Let us say the screens. Screens are you know used to separate out the particles of different size in general. So these screens in general we might have seen in different places not only in this industries but also in household purposes as well. So screens are like this. So the screens these openings are square openings actually to be frank. The drawing is not appearing like that but it is perfectly square opening. Let us say within the screen you take one linear inch distance. So this one linear inch distance I am taken here and then redrawn here. So within this one linear inch distance 1, 2, 3, 4 like how many? 1, 2, 3, 4, 5 openings are there. So then such a screen is known as the 5 mesh. Then what do you mean by minus 5 mesh? That means the material which is having size less than the 5-mesh size. How do you know the size of such mesh? Let us say 5 mesh distance we made 5 parts in one linear inch. So 1 by 5 inches minus thickness of wire that has been used for the construction of this mesh. So then you get the opening size. So whatever the material which is having less than opening would be passed through and such materials are represented as minus 5 mesh. Whatever the material having the size more than this opening they will not be passed through and they will be retained on the mesh. Then we call it plus 5 mesh. Likewise 20 mesh, 4 mesh, 1 mesh or 100 mesh whatever it is same way of representation. What you see? Bigger is the mesh number, smaller is the opening. Now second one is the grinding. So these grinders are like you know cylindrical vessels like this. These cylindrical vessels are having provision to rotate. In these vessels what you do? You take material. What material? Whatever the material that you wanted to size reduce that you take here. In these kinds of grinding equipment already what we have? We have you know grinding medium that is you know it may be steel ball or wooden ball or may be rods etc. of different size would be there. Now when you rotate this drum what happens? These particles or whatever are there they will be moving up towards the top periphery and then they will be falling down. When they fall down this grinding medium and then material to be size reduced they will be interacting and then smaller fragments may be taking place like this. So wet or dry grinding may be carried out in presence of balls, pebbles or rods.

Principle is same. Only the grinding medium is changing. So feed may be minus 4 to 100 mesh size that means the feed is having as big as 4 mesh size. 4 mesh in the sense 1 by 4 inch minus thickness of wire. So approximately let us say 0.25 inches minus let us say 0.005 inches is the thickness of the wire. So then 0.245 inches would be the opening. So that means the material having 0.245 inches or if you take let us say 10 mesh then 1 by 100 inches minus thickness of wire. So that if you take 0.01 inches minus 0.005 inches is the construction or the thickness of the wire that is used for construction of the screen. So then you will be having 0.0995 inches of the size. So from 0.24 inches to approximately 0.0995 inches size material can be used as a feed and then you can do this size reduction to further smaller size like this and then what would be the ratio 10 to 15 to 1. That is the size reduction ratio. Let us say if you have 0.01 inches as the feed material then you may be having the product 0.001 inches of the product such smaller size it is possible. So then like that ultrafine grinders etcetera or then cutting etcetera those kinds of things are there we are not going into details of those things. As I already mentioned crushing is the coarse reduction operation and then grinding is the intermediate reduction operation ultrafine is the fine reduction operation. Cutting is the specific size reduction operation as per requirement 4 or cubes or something like that of a definite size. Like that different size reduction processes are there, their working principles and then equations and all are not part of the course so then we are not discussing them. So sometimes when you take this process though these are the size reduction ratios provided here but in general there would be finer also. There would be some materials very fine some may be very bigger ones also compared to the whatever it is produced. These numbers whatever produced are the average size of the material. So, when you consider the size reduction what does it mean by product is having 0.001 inches these things. So it may be from 0.005 inches to it may be 0.0005 inches also such smaller is also possible a kind of average number is provided here. Sometimes oversize reduction takes place and then you may need to do the size enlargement. So pelletizing is one of such kind of size enlargement. It is also used for making pellets or medicinal tablets etc or catalyst pellets etc. Catalyst may be very fine particles of the catalyst may be there. Sometimes you may need to make them in a pellet form before putting into the reactor. For that purpose these are used. Let us say fine particle whatever are there you take here and then you take specified amount as per the requirement and then you apply the pressure so that you can get the pellets like this as a product. Now you see small size particles now you are getting bigger size pellets like this.

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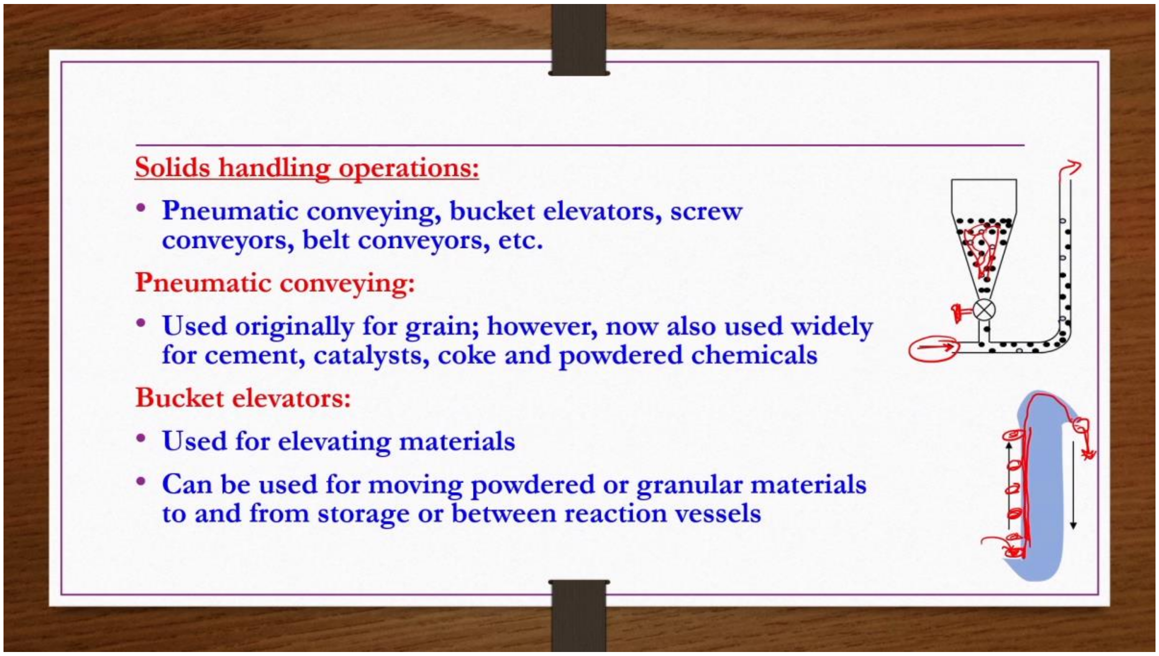

Solids handling operations sometimes it is required to handle the solids also what do you mean by handling solid operation it is not only the storage it is transporting the solids from one location to the other location or from the in a one-unit operation to the other unit operation or to the reactor where the unit process is taking place is required. So for that purpose the solids handling operations are used. Some of them are pneumatic conveying, bucket elevators, screw conveyors, belt conveyors etc. For example, pneumatic conveying used originally for grains however now also used widely for cement catalyst, coke and powder chemicals etc. So let us say for example, this is the container in which you have taken the particles, there is a opening here opening wall is there and then from here bottom there is a provision for the gas or air to allow. So it has to be inert. So when you wanted to take this material to the next level you have to open the wall and then allow this air to or the gas to flow through at a higher speed so that this particle would be carried up to the next level. This is known as the pneumatic conveying. Bucket elevators used for elevating the materials can be used for moving powder or granular materials to and from storage or between reaction vessels. For example, so here a kind of belt conveyor kind of thing is there. So to this one different locations these buckets are attached. They are fixed in position. So now what happens when this moves this belt or shaft to which these buckets are attached. So these buckets would also be moving. So let us say from here in this bucket the material whatever is there that you have to be transporting so that you taken here. So when it moves up like this, when it reaches to the top location the position is such a way that automatically the bucket would be tilted out and then that material should be delivered to the other location. And then since the shaft is rotating continuously the cup process can go continuously. This is known as the bucket elevators process.

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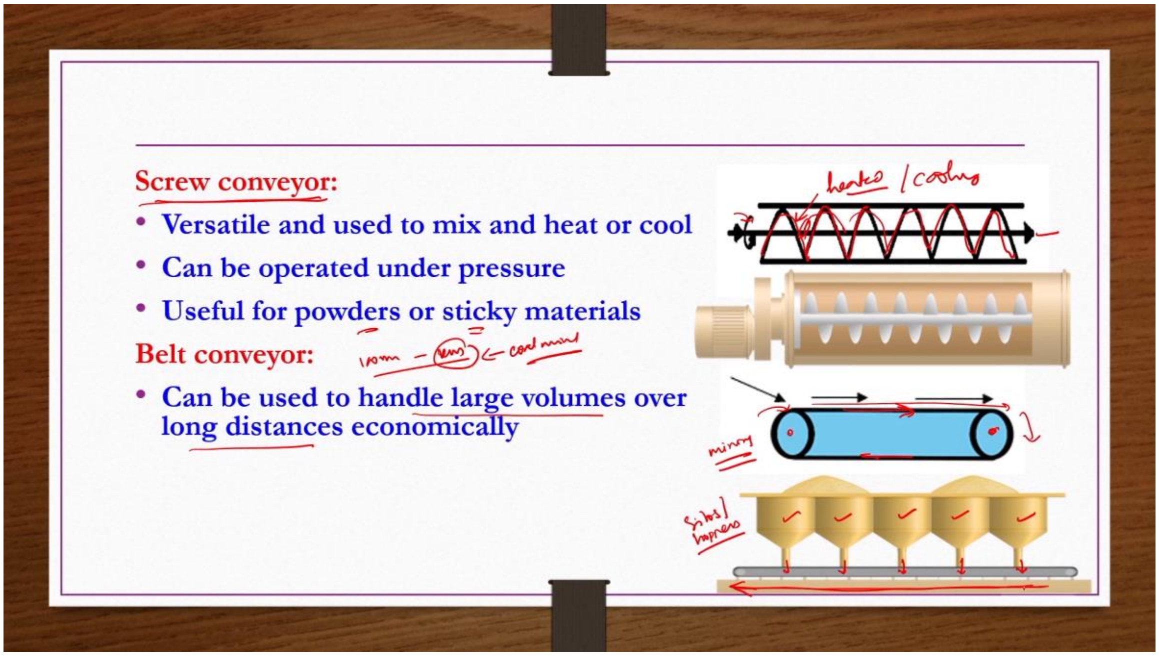

Screw conveyor, they are not only used for the transporting the material from one location to the other location, they are also used for the mixing as well as the heating or cooling also. They are very versatile. So let us say whatever the material that is there here, so you wanted to transport to the next level. So you take it here. So now here the screws are there. So the material is taken from one level to the other level when the screw is moving. So let us say if you wanted to heat the material, so then the screws are at heated conditions, high temperature conditions to which this you wanted to heat this material. Similarly, cooling if you wanted to do that is also possible. A typical screw conveyor is shown here. It can be operated under pressure as well, useful for powders and sticky materials. If you have powdered or sticky material, then bucket elevators are not going to be useful. Under such conditions, screw conveyors are the best ones. Belt conveyors in general, they are used for distance of few meters, 100 meters to several kilometers also they are used. In mines, mostly coal mines, etc., these belt conveyors are mostly used, especially when you need to handle large volumes of the material over long distance, several kilometers also. So let us say you have done the mining under mine and then lot of material is there. So that has to be brought to the surface. So what you do, the belt conveyors are used. So whatever the mined material is there, that would be dropped here and then this belt is rotating on two wheels like this. So when this belt rotates, whatever the material is there, that would be carried forward along with the belt and then delivered to the other end. Pictorial representation is also shown here for the silos. Silos and hoppers are used for storage of size reduced material. If you wanted to take them to the next level for the subsequent unit processes or unit operations, so such kind of belt conveyors are used. The material taken from the bottom onto the belt and then that belt is moving. So since the belt is moving, so the material on the belt whatever is there, that will also be moving and then transported.

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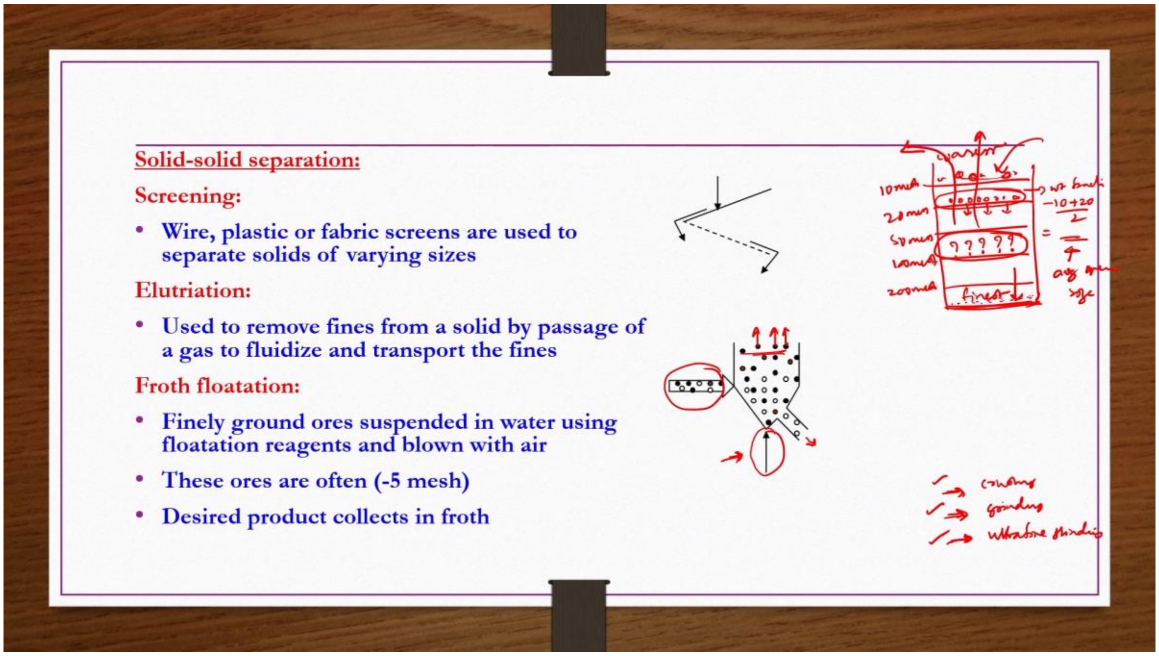

Solid-solid operations, if you see screening. Just now we have seen crushing, grinding and then ultrafine grinding, etc. When you do this kind of coarse intermediate or fine size reduction operations, then what happens? You get all ranges of the particles, not only you get coarse here and then intermediate here and then fine here, right? So then size separation is required. So for that purpose, different screens whatever I have shown, they are placed one onto other like this with some turn distance, right? So the bottom one is having the largest mesh number, that means very finest one. Then next largest one is above on it. Like that all the meshes whatever are there, they are placed like this. So based on the size reduction, whatever the material is there, so that is poured here, right? Based on the size of the material, whatever the material having the size less than 20 mesh size, they will be passed through here. Whatever the material is having the more than 20 mesh size, they will be retained here. Like that, that is going to be true for all the things. At the bottom, we are having the pan in which we are getting the finest material which have passed through 200 mesh. Now the weight fraction of this material you can find out by weighing it. You collect how much material is there on the 20 mesh, that weight divided by the total feed weight that will give you the weight fraction of the material that has been retained on 20 mesh, right? And then what is the average size of this material?

That would be the average of minus 10 opening plus 20 opening mesh divided by 2, that is whatever the material that has passed through 10 material and then whatever the material that has retained on 20 mesh, so in between it is there. So average opening of these 2, 10 opening size, 10 mesh opening whatever is there that one plus 20 mesh opening whatever is there that one divided by 2 if you do, that would be the average opening or average size of the material that is being retained on the 20 mesh. Like that different materials you can get. So coarsest one you will be having at the top and then most finest one would be at the bottom. As per your requirement, you have to select the screens and then collect the material appropriately.

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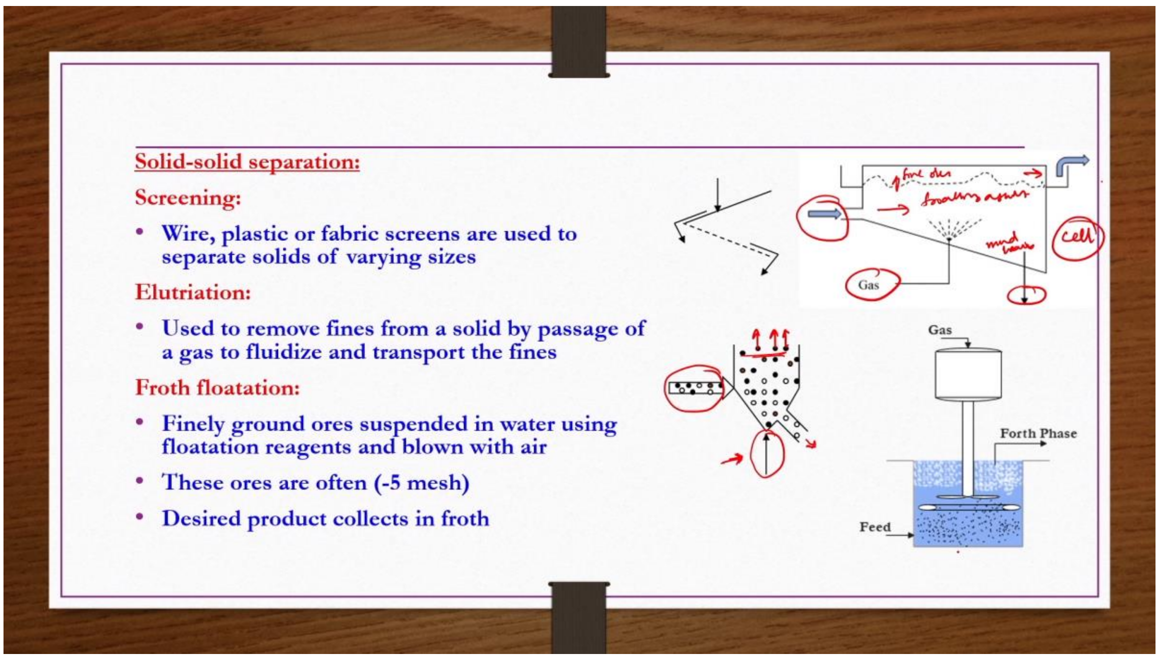

Let us say whatever the material retained between 50 to 100 mesh or whatever passed through 50 mesh and then retained on 100 mesh that is going to the most suitable for your process. That you collect and then take it as a final product for the subsequent operations. Whereas the finer one you can do the size enlargement, pelletizing, etc. Whereas the coarse one you can take back for the further size reduction, etc., those kind of operations you can do. So the solid-solid separation for that purpose screening is one used. So wire, plastic or fabric screens are in general used to separate solids of varying sizes and then this way also it is represented in general. Illiteration used to remove fines from a solid by passage of a gas to fluidize and transport the fines. Let us say whatever the material that you have, mixed materials, size reduced material which is having all size like minimum, like fine, intermediate, coarse material, all of them you take in a container and then from the bottom of that one you allow a gas, inert gas or air to pass through, right? So whatever the material finer ones is there, so that would be carried away along with the gas because of the smaller size whereas the bigger size particle, heavier and bigger size particles would be collected from the bottom like this because they are not being able to carry it away along with the fluidizing gas medium. The fluidizing velocity or the velocity of these medium gas or air whatever you have taken you should calculate such a way that it will be carrying out only the fine particles not the coarse particles, okay? Likewise froth flotation is another unit operation which is used especially for recovery of very expensive important minerals in general. Finely ground ores suspended in water using flotation reagents and blown with air. These ores are often minus 5 mesh, this desired product collects in the froth. Let us say pictorially if you see froth flotation whatever the finely divided ore is there that you take in a container in which you have the water and then frothing agents also there which are in general some kind of oils. To this mixture, the gas or air is also being blown from the bottom so that more froth is forming. This froth carrying the fine ores etcetera at the top and then they will be collected along with the froth as a product whereas the mud etcetera kind of heavier materials they will be settling at the bottom and then collected from the bottom as a wastage. Such kind of froth flotation cells, this is one cell only, n number of cells in general used as per the requirement of the purity etcetera. This is another representation of froth flotation again.

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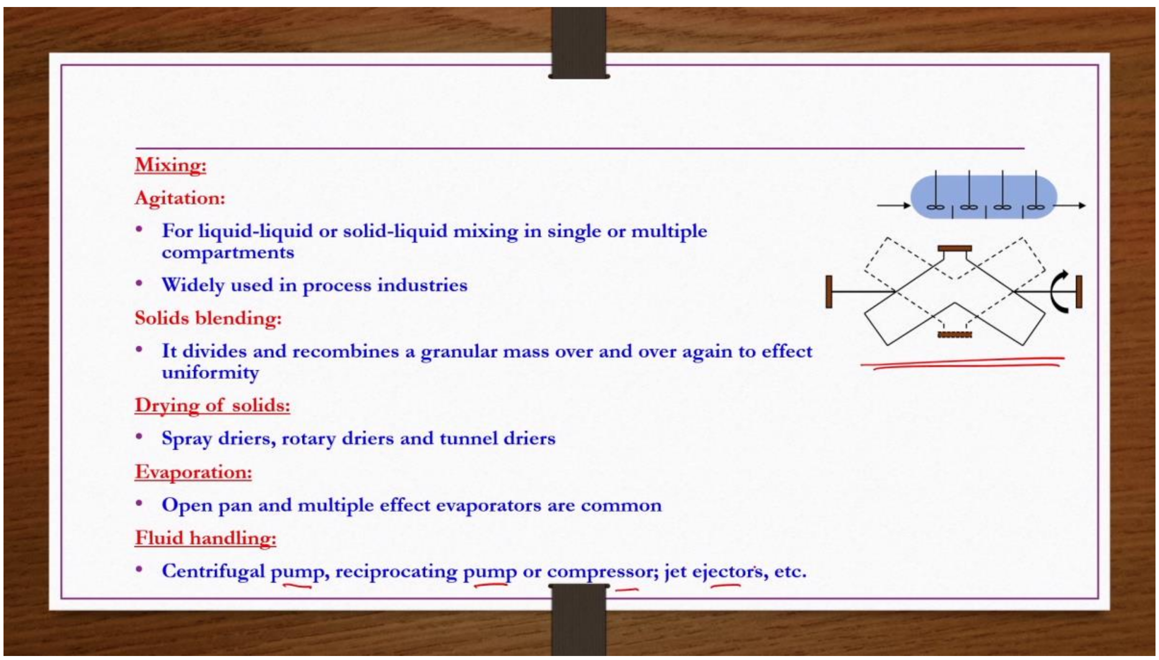

Like that mixing equipments are also there like agitation. For liquid or solid liquid mixing, a single or multiple compartment are there as shown here widely used in process industries. Solids blending, it divides and recombines a granular mass over and over again to effect uniformity. Similarly, like screw conveyor they look like or they may be projected like this also. Drying of solids also important. Several dryers are there like spray driers, rotary driers, tunnel driers etcetera.

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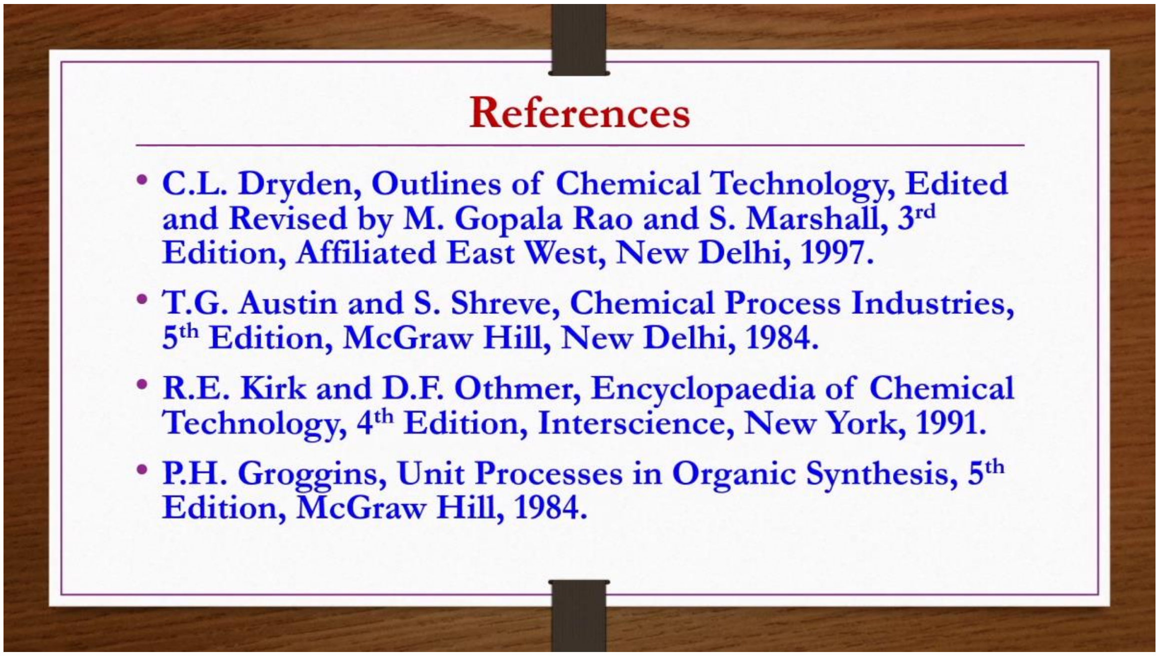

Then evaporation, it can be open pan, single effect, multiple effect evaporators, anything it can be different options are there. We are not going into the details of all of them in this course itself. Then fluid handling is there. Further different types of pumps like centrifugal pump, reciprocating pumps, compressors, jet ejectors, etcetera are utilized. References for this lecture are provided here. Thank you.