Chemical Technology
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Module - 1
Introduction
Lecture - 3
Basic Principles of Unit Process and Unit Operations
Organic Chemical Industries

We are discussing the Chemical Technology course organic part and in this, we are discussing the module 1. In module 1 lecture 1, we discussed about the status of the chemical process industry, in module 2 in lecture 2 we discussed about the raw material for the chemical process industry. And lecture 3, we will be discussing about the various Basic Principles of Unit Processes and Unit Operation in Organic Chemical Industry.

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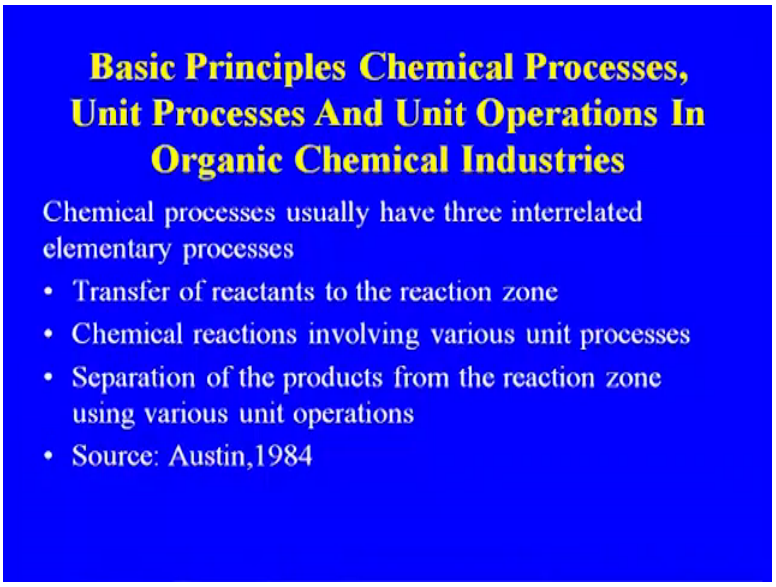

A basic principle of the chemical process industry, chemical process usually have 3 interrelated elementary processes, transfer of the reactants to the reaction zone, chemical reactions involving various unit processes and then, the separation of the products from the reaction zone using various unit operation.

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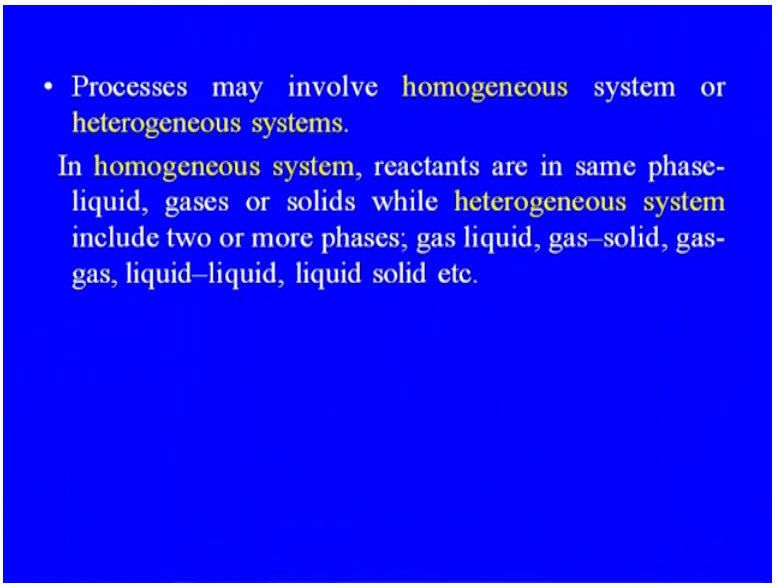

Process may involve homogenous system or the heterogeneous system, in homogenous systems reactants are in same phase liquid, gasses or the solid. While heterogeneous system include two or more phases gas liquid, gas solid, gas gas, liquid liquid, liquid solid, etcetera.

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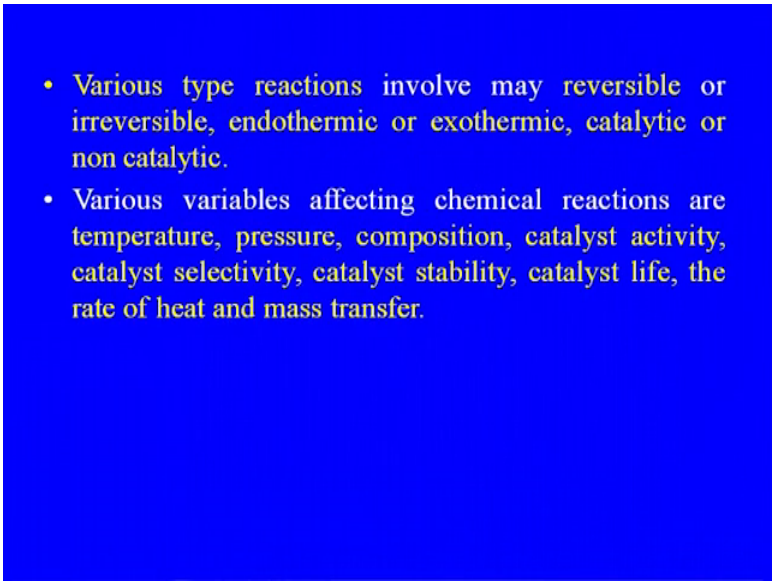

Various type of the reaction involve many reversible or irreversible, endothermic or exothermic, catalytic or non catalytic. So, you can see the chemical process industry a very complex of very complex nature. Various variables affecting the chemical reactions

are temperature, pressure, composition, catalyst activity, catalyst selectivity, catalyst stability, catalyst life, the rate of heat and mass transfer.

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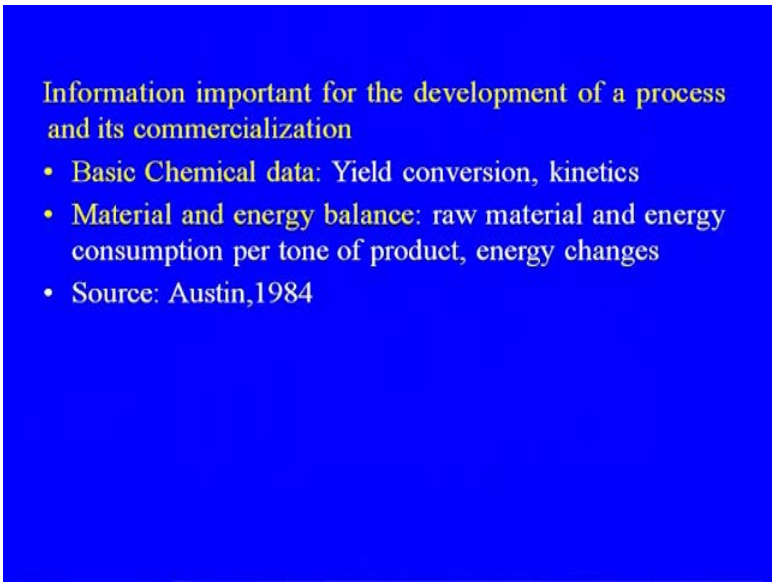

Information important for the development of a process and it is commercialization that is the basic chemical data, yield conversion, kinetics. Material energy balance, raw material energy consumption per tone of the product, energy changes.

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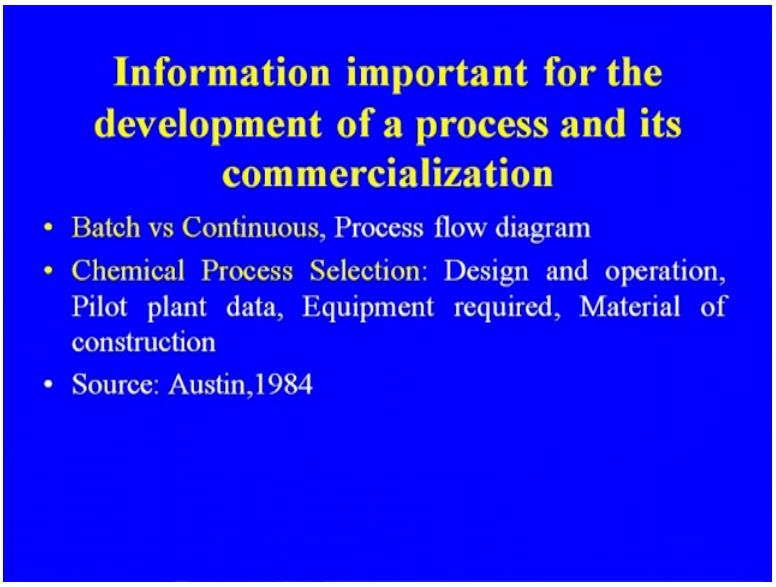

Information important for the development of the process and it is commercialization, batch or the continuous process, chemical process selection design and the operation, pilot plant data, equipment required, material of construction.

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Chemical process control and instrumentation, chemical process economics, competing process, material and energy cost, labour, overall cost of the production, this this is very important aspect incase of the chemical industry. Because, the cost of the raw material that is varying from 40 to 50 percent, in some of the cases it may be 20 to 30 but, in many cases it is around 40 percent of the total cost and so, the cost of the raw material, energy, labour, overall cost that is very important aspects.

Market evolution, purity of the product and uniformity of the product for further processing plant location because, this is the one of the very important factor, while locating any chemical industry or any industry. We will have to take into consideration many factors, whether the location of the plant will be economical or not, availability of raw material and other aspects we will have to see.

Chemical process control instrumentation, you see the there has been vast changes in the chemical process industry and the control and instrumentation part that has played very important role in the development of the chemical process industry. And now, the chemical process industries very complicated and lot of the instrumentation is there. Another aspect in case of the chemical process industry is chemical process economics,

competing process, material energy cost, labour, overall cost of the production, market evolution, purity of the product and uniformity of the product for further processing plant location.

Now, the some of the another changes that has taken place in the chemical process industry and now, they are playing very important role in deciding the location and at the same time, the processes, the environment health and safety and hazard part.

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Because, now the concept that has changed from the environment to health or safety now, it is the see that is the safety, health and the environment. Construction, erection because, after deciding the everything about the location everything, the next part that that is the construction, erection and the commissioning of the plant. Management for productivity and creativity, that is one of the very important aspect in case of the any industry, training of the plant personnel and motivation at all levels.

Because, unless until the people are motivated, we cannot achieve our target, we cannot achieve the our improve or productivity. So, the participation of all the personnel, whether at the junior level or the senior level that is very important for improving the productivity. Research development pattern so, this is also because, continuous effort that is being taken for the development of the process, for improvement of the yield or the conversion in the chemical process industry.

So, in house research and development, that is also very important for any development inside the plant.

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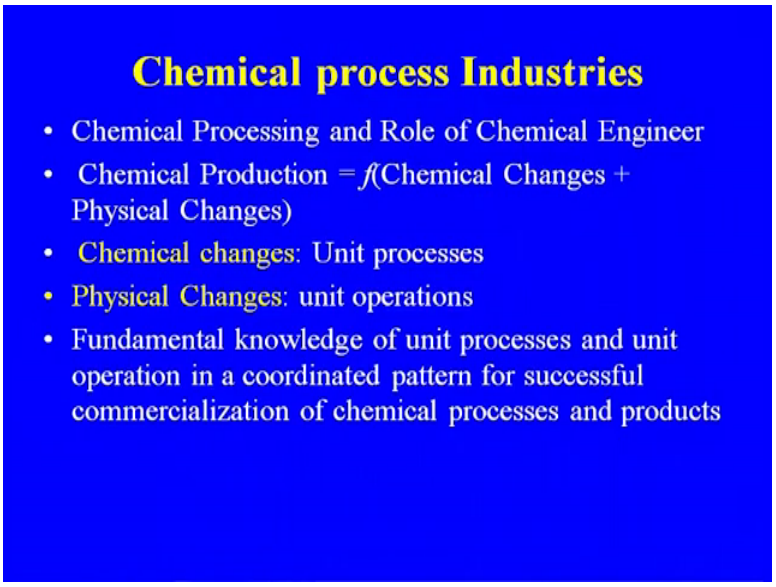

Chemical process industry, if you see that is the chemical production, that is the function of the chemical changes and the physical. These are the two things that is happening in case of any chemical plant, chemical changes and that is the chemical by the reaction of the some of the reactants we are producing some product. And then, the products which is made, how to separate it for that, we are having the unit operation that is the physical changes that has taken place.

So, chemical change that that is dealing with unit process and physical changes that is dealing with the unit operation. Fundamental knowledge of the unit processes and unit operation in a coordinated pattern for successful commercialization of chemical process processes and the products is very essential and this is the changes, that has taken place. And what about the changes now we are seeing in case of the chemical process industry, if you compare the chemical process industry of the 1950 and the now, there has been sheer changes in the capacity, energy conservation measures and the environmental processing control measures.

Even the capacity wise, earlier we used to have a very low capacity plant now, we are having the very high capacity plant. Then the earlier, the separation of the products which we were getting from the various unit process, that was a very difficult task

especially, in case of the any close warning points were there or the isotopic mixtures was there.

So, in that case the and the purity of the product, at that time it was difficult to get the very pure component of from a reaction. So now, the what is happening because of the development, which has taken place in case of unit operations now, the separation that has become much more easier. And one of the example that is, the absorption and liquefaction that is being used in case of the petroleum industry. So, the chemical process is combination of the unit processes and unit operations.

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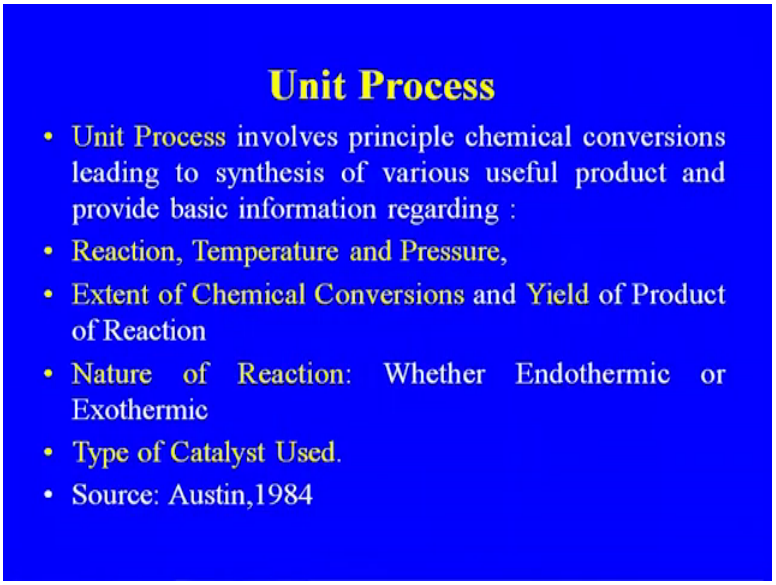

Unit process involves principle chemical conversion leading to synthesis of the various useful product and provide basic information regarding reaction temperature and pressure. Because, this is the initial stage, how the development in the chemical engineering that took place, that was the initially. It was the chemistry, chemistry to industrial chemistry, industrial chemistry to the chemical technology and then, it was the chemical technology to the chemical engineering.

Because, some of the information about the various process that was available earlier also but, how to go for the separation of the products, which we are getting. How to improve the yield, that is the catalyst development or the what are the things that you can use for the controlling the temperature then, the instrumentation part, all those

development that has been there, only because of the coming of the chemical engineering curriculum.

The extent of the chemical conversion and yield of the product of the reaction, nature of the reaction, whether it is endothermic or exothermic type of the catalyst. There has been always continuous development in the catalyst for the in the chemical process industry just to improve the productivity, just to increase the yield, just to increase the it is resistance towards the various poisonous catalyst poisons, which are there in especially in case of the petroleum industry.

So, this is the some of the development, which are taken place and the combination of the both the knowledge of the unit process and unit operation that is very important. Unit processes now we will discuss about unit process in the chemical process industry.

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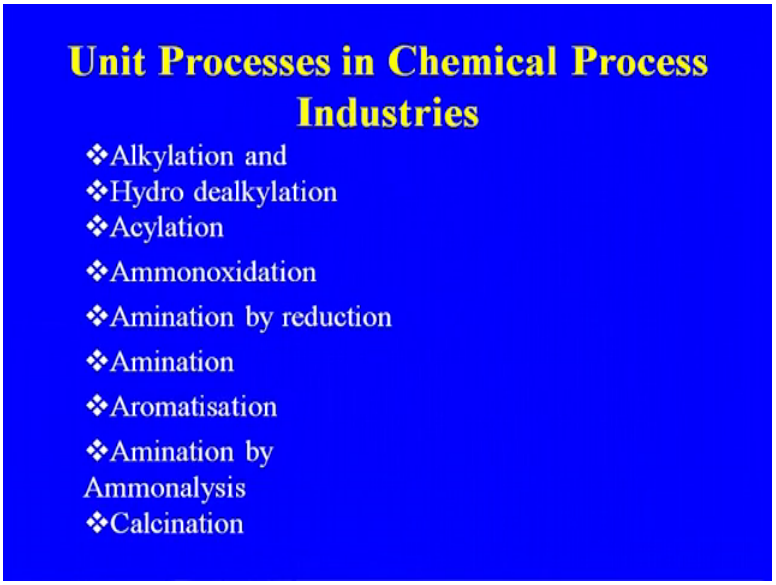

What are various unit process, that we are using alkylation, hydro alkylation, acylation ammonoxidation, amination by reduction, amination, aromatization, amination by ammonolysis, calcination.

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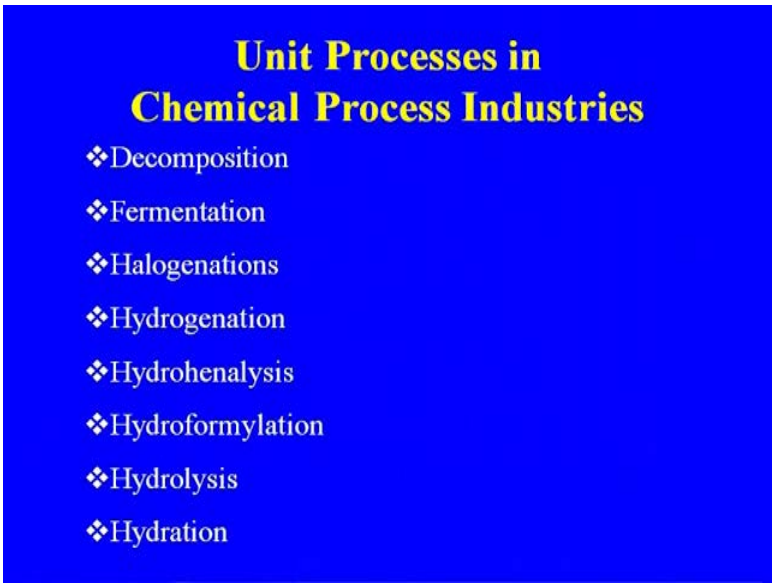

Decomposition, fermentation, halogenations, hydrogenation, hydro sorry hydroformylation, hydrolysis, hydration.

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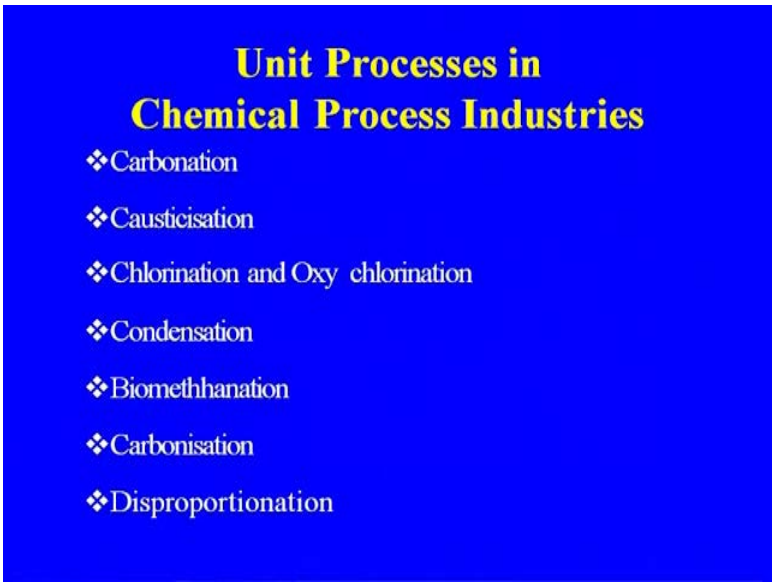

Carbonation, causticisation, chlorination and oxy chlorination because, this is the process chlorination oxygen. Now, what we are having in case of the earlier, in the manufacture of the vinyl chloride, we were using the chlorination now, we are using the oxy chlorination. Condensation, biomethhanation, carbonization that is very important in case of the coal carbonization, biomass carbonization. Disproportionation that is

important in case of the, when you are converting the toluene to the more value added product xylene and the benzene.

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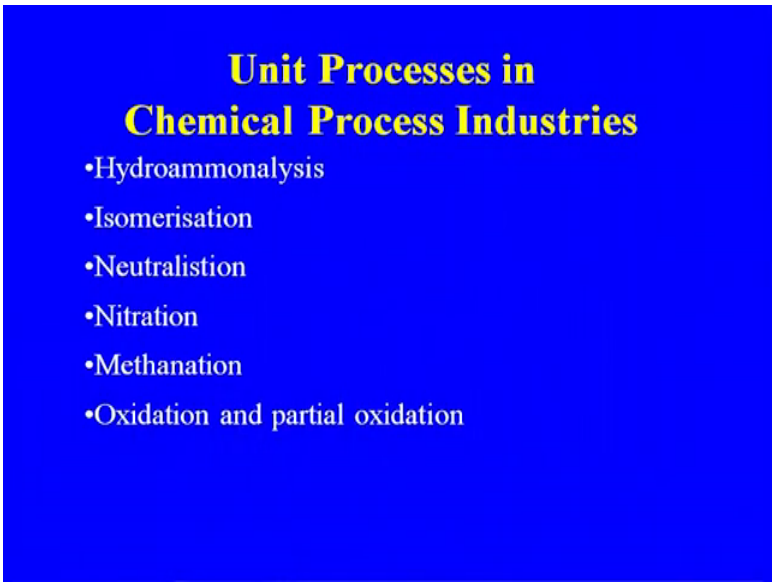

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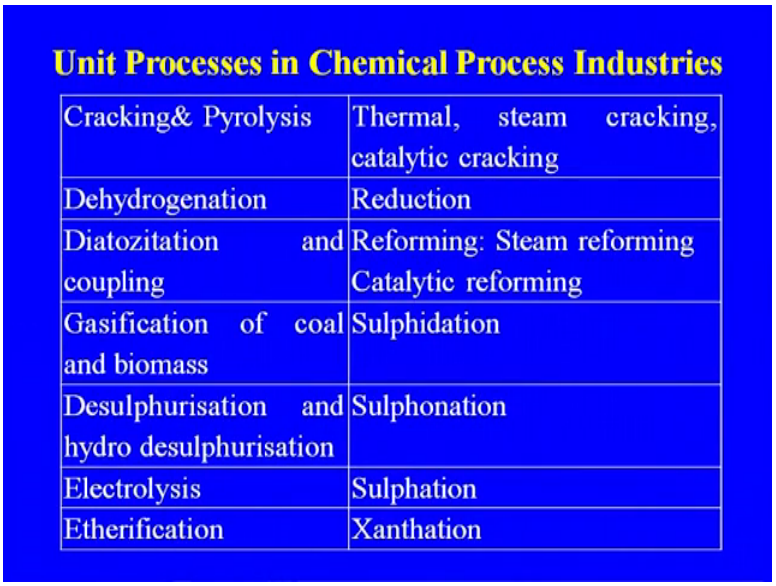

Hydroammonalysis, isomerization, again isomerization that is playing very important role in case of the chemical process industry, in case of the refinery, that we are using for improving the octane number of the low octane naphtha. Similarly, incase of the isomerization of the metaxylene to paraxylene, that we are doing in case of the

paraxylene manufacture, neutralization, nitration, methanation, oxidation and the partial oxidation.

Other unit processes now, that has become very common that is, the cracking and pyrolysis, dehydrogenation, diatozitation, coupling and the gasification, and of coal and biomass, desulphurization, hydro desuplhurisation. Because, there has been lot of the changes in the case of the desulphurization, hydro desulphurisation and the requirement especially, in case of the petroleum refinery industry to meet the norms of the various fuels.

It may be gasoline or the diesel or to meet the requirement of the feed for the various processes, electrolysis that is very important in case of the caustic chlorine manufacture. Etherification we are using at the various stages in chemical process industry, thermal and steam cracking, catalytic cracking because, this is the how the evolution that has taken place in case of the cracking process. Earlier, it was the only thermal cracking then, thermal cracking to catalytic cracking just to improve the economy of the process and reduce the temperature and to have the better quality of the product.

Steam cracking, that was developed for the, actually the cracking of the naphtha cracking of the gasses where, we are producing the olefins. Reduction, reforming, steam reforming, catalytic reforming, steam reforming that is very important for the manufacture of the hydrogen, for the manufacture of the synthesis gas. Catalytic reforming, we are using in the refinery and the petro chemical complexes for the manufacture of the for improving the octane number of the naphtha.

And at the same time, for the production of the paraxyle, sulphidation, sulphonation because, sulphonation in many of the process, we are using sulphation. Xanthation, that is the process we are using in case of the viscous rayon, these are the some of the important chemical reaction, that we are coming across in the chemical process industry.

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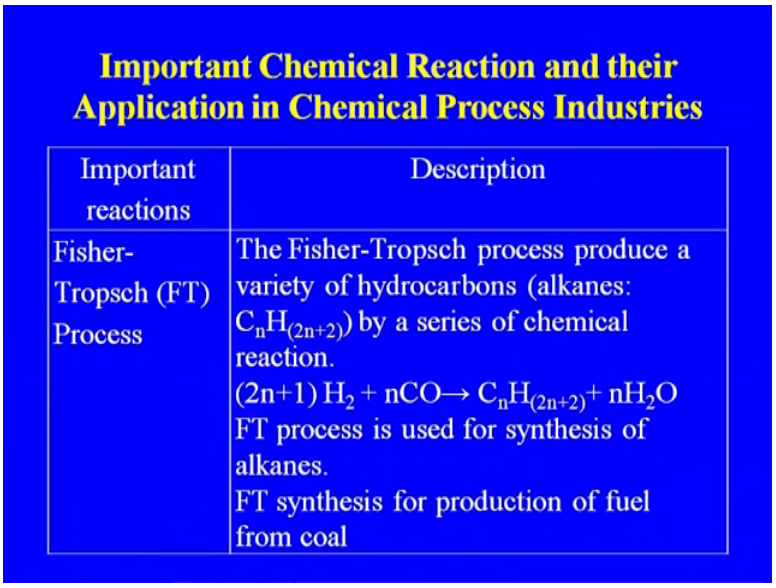

That is the fisher tropsch process, the fisher tropsch process produce a variety of hydro carbons, alkanes by a series of chemical reaction that is, the (()) reaction and that is the FT process used for the synthesis of alkanes, FT synthesis for the production of fuel from coal. Because, that has become very important after because now, the many places now we are using the coal for the production of the synthesis gas then, from synthesis gas to fuel and value added for other value added product hmm chemicals.

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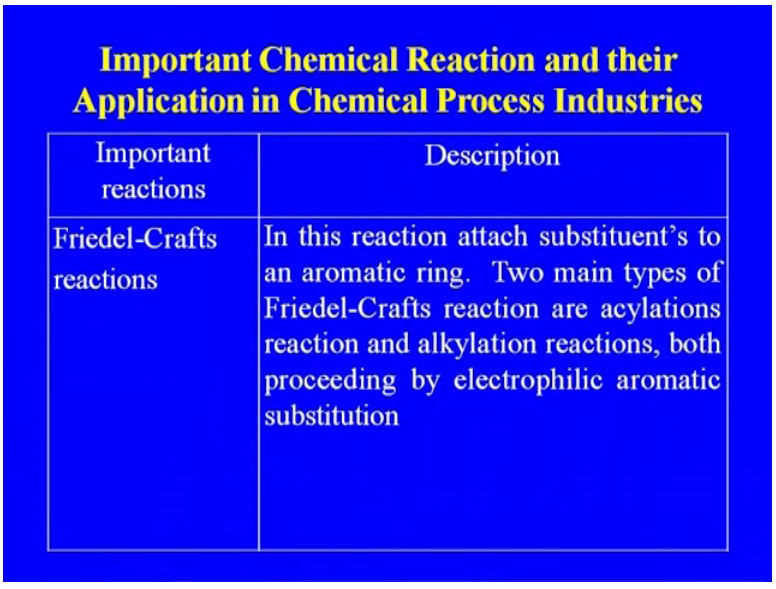

Friedel craft reaction that is also very important, in this reaction attach substituents to an aromatic ring, two main types of the friedel craft reaction or acylation reaction and the alkylation reaction. Both proceeding by eloctrophilic aromatic substitution, this is reaction that is taking place in case of the friedel craft reaction.

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Important Chemical Reaction and their Application in Chemical Process Industries

Important reactions	Description
Oxo synthesis	In this process Isomeric mixture of normal- and isoaldehydes get produced by utilizing syngas (CO and H_2) and olefinic hydrocarbons. It is exothermic process, this process thermodynamically favorable at ambient pressure and temperatures. This reaction also called as hydroformylation reaction. $RCH{=}CH_2+CO+H_2 \rightarrow RCH_2CH_2CHO + R(CH_3)CHCHO$

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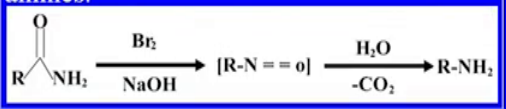
Important Chemical Reaction and their Application in Chemical Process Industries

Important reactions	Description
Hofman reaction	In this process, organic reaction of primary amide converts into a primary amine with one fewer carbon atom. Hofman process typical examples are conversion of aliphatic amides to aliphatic amines and aromatic amides to aromatic amines. 

Oxosynthesis, in this process isomeric mixture of the normal and isoaldehydes get produced by utilizing synthesis gas and olefinic hydrocarbons. It is exothermic process,

this process thermodynamically favorable at ambient pressure and temperature, this reaction also called a hydrofomylation reaction.

Hofman reaction, in this process organic reaction of the primary amide converts into a primary amine with one fewer carbon atom. So, this is also very important in case of the chemical process industry and the reaction, that is taking place this, this is the reaction which is taking place in case of the Hofman reaction. Beckman rearrangement, that is one of the very important reaction that is taking place especially, in case of the manufacture of the caprolectum, that we are manufacturing.

Caprolectum, in the process of making of the caprolectum from cyclo action, that the process in the last process in the beck man arrangement.

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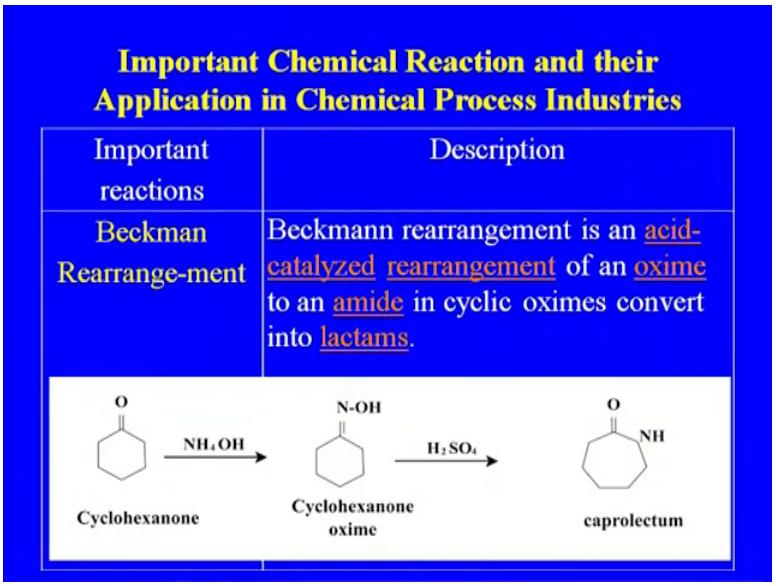

Where, the acid catalyzed rearrangement of a oxime to an amide in cyclic oximes convert into lactams, that is the caprolectum that we are getting. So, this is the this is the reaction which is taken place in case of the caprolectum manufacture. Free radical reaction again they are very important in many of the polymerization reaction or in many of the other reaction, that is the free radical reaction that is taken place.

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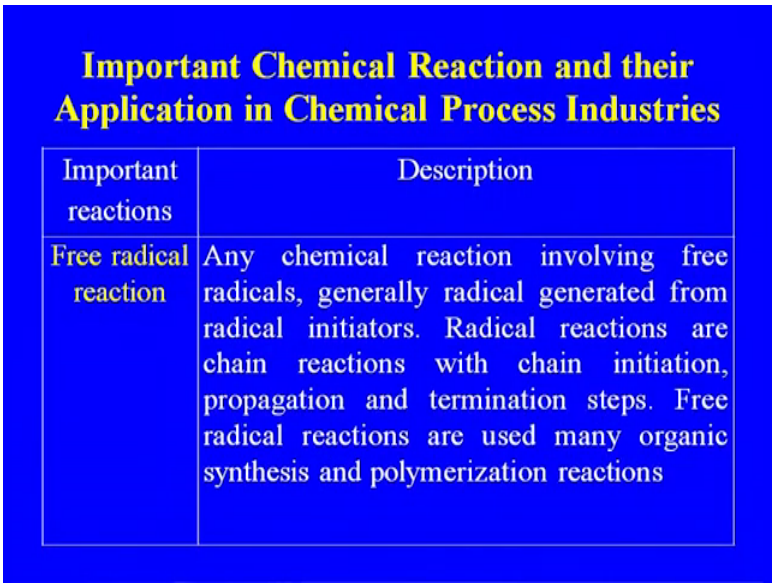

Any chemical reaction involving free radicals, any radical generated from the radical innovative initiators, radical reactions are chain reactions with chain initiation, propagation and termination, these are the three steps normally that is taking place in case of the free radical reaction. Free radical reactions are used many in many organic synthesis and the polymerization reactions.

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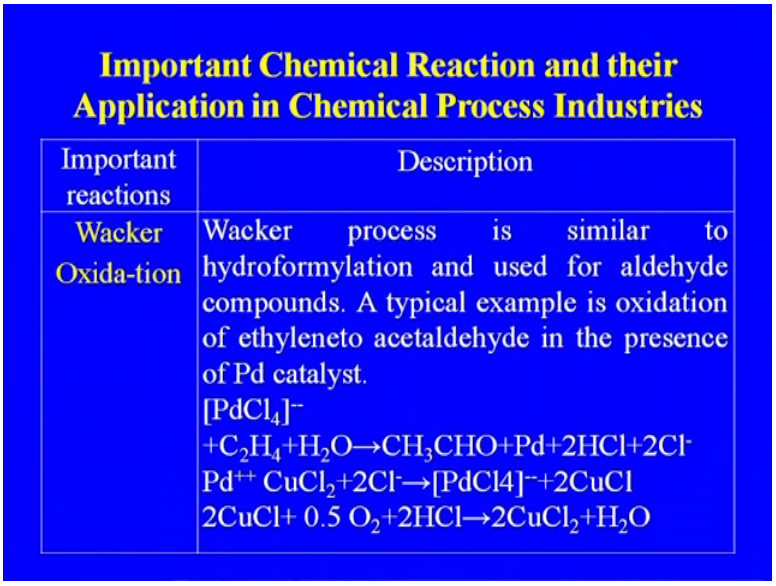

Wacker oxidation, wacker oxidation is similar to hydrofomylation and used for aldehyde compounds and this is the paladium catalyst that we are using in this reaction, this is the

reaction that is taking place. Nitration that is one of the very important reaction in case of the chemical process industry.

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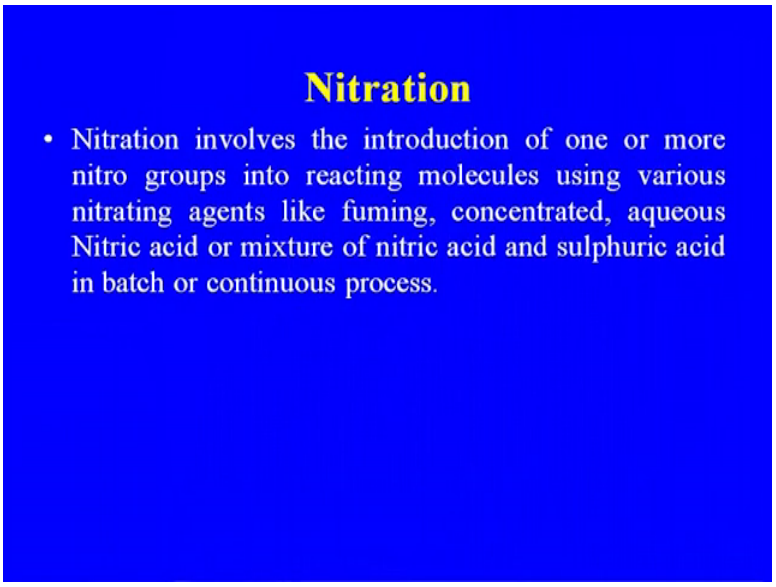

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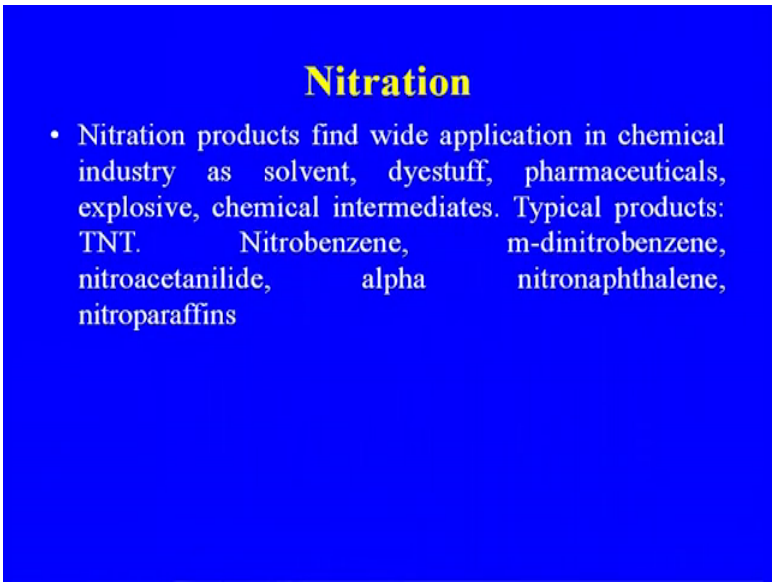

Nitration involves the introduction of one or more nitro groups into reacting molecule using various nitrating agents like fuming, concentrated aqueous nitric acid or mixture of nitric acid. Because, the mixture of nitric, that mixed acid that we are using in case of the manufacture of the TNT, Tri Nitro Toluene that there. And in many of the other chemical

process industry, we are also using the mixed acid in the state of the nitric acid. So, that is also coming in this but, that is also a part of the nitration.

Nitration products find wide application in chemical industry as solvent, dyestuff, industries and pharmaceuticals, explosive, chemical intermediate. Typical products are TNT, nitro benzene because, nitro benzene that is very important product in the chemical industry, meta dinitrobenzene, nitroacetanilide, alpha nitronaphthalene and nitroparaffins.

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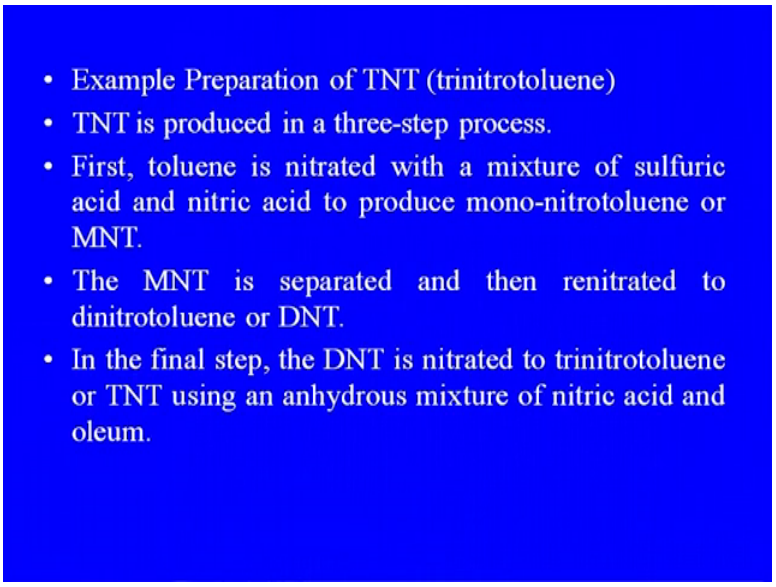

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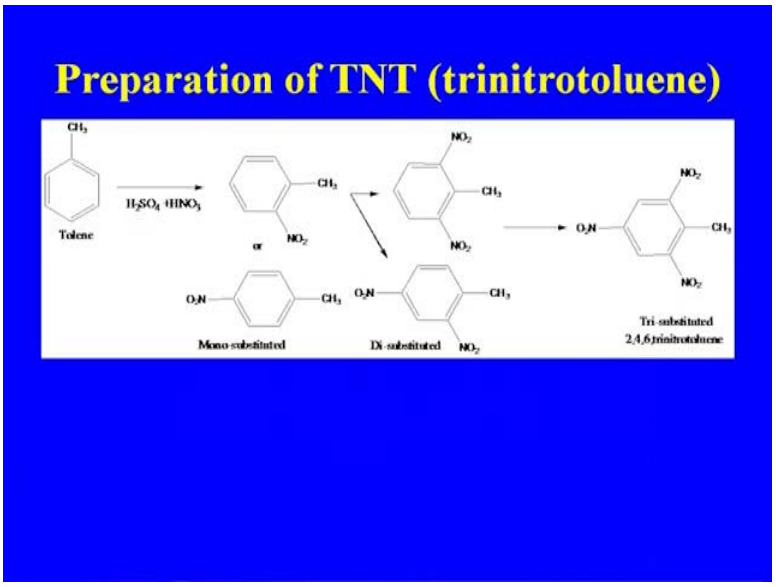

Example of preparation of the TNT, TNT is produced in a three steps that is, the in the first step MNT is made and there, we are using the mixed acid cat. The as a catalyst MNT is then, they it is we are getting DNT and from there, further nitration we are getting the TNT.

This is the reaction that is taking place in making of the nitrotoluene from the toluene, halogenations, halogenation that is also very important reaction in case of the chemical industry because, many of the halogenated products we are using in some or other form.

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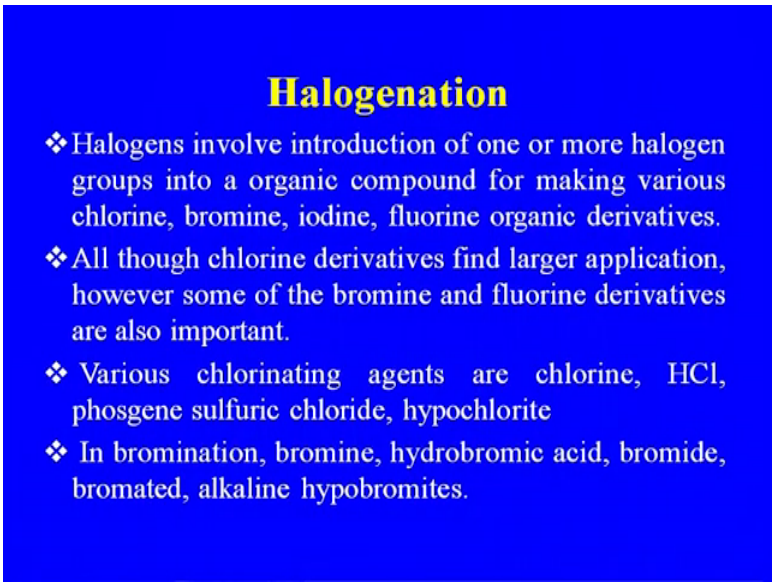

So, halogen involves introduction of one or more halogen groups into a organic compound for making various chlorine, bromine, iodine, fluorine, organic derivatives. One of the very important reaction that is in case of the halogen, that the manufacture of vinyl chloride chloride through ethylene dichloride, ethylene dichloride again that is produced by the chlorination of the ethylene. Although the chlorine derivatives find larger application however, some of the bromine and fluorine derivatives are also important in case of some of the brominated compound also, we are using in in the process.

Various chlorinating agents are chlorine, HCL, phosgene sulfuric chloride or hypochlorite, that we are using in bromination, bromine, hydrobromine hydrobromic acid, bromide, bromated, alkaline hypobromites, these are the some of the bromination brominating agent that we are using.

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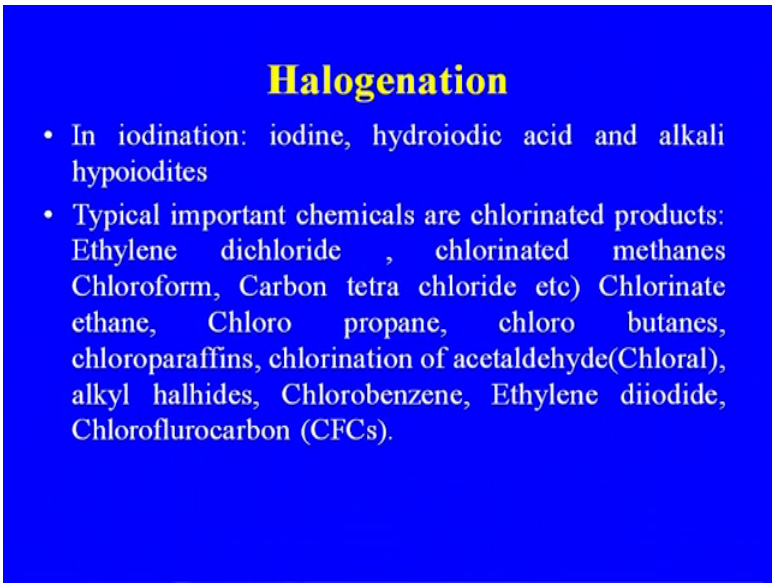

In iodination, iodine, hydroiodic acid and the alkali hypoiodites that we are using, typical example are chlorinated products ethylene dichloride, chlorinated methane, chloroform. Because, in case of the chlorination of methane, number of products you are getting during the chlorination. That is the chloroform, carbon tetra chloride then, the chloro ethane, chloro propane, chloro butanes, chloro paraffins, chlorination of the acetal dehyde, alkyl halides, chlorobenzene.

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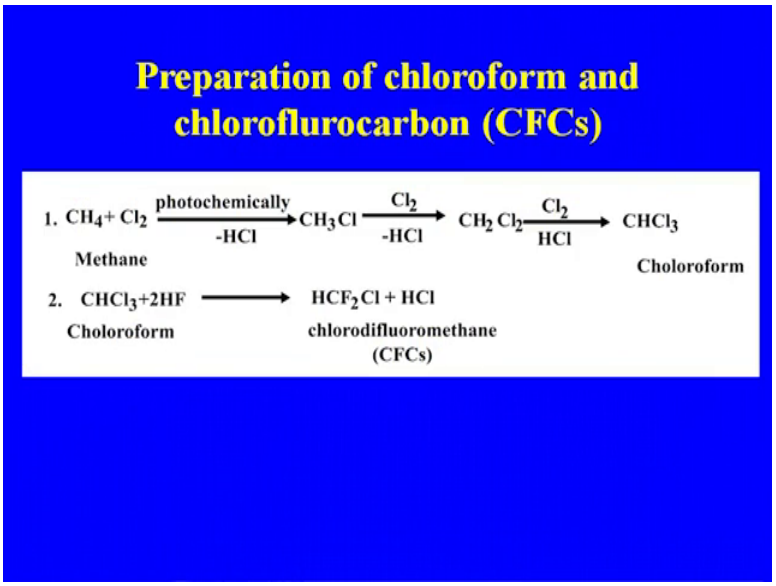

Chlorobenzene because, that is the starting material for the nitro benzene so, chlorobenzene. This was the earlier process, other processes are also there but, chlorobenzene to nitrobenzene, ethylene diiodide, chloroflurocarbon that is the use of the fluorine.

This is the reaction that is taking place in case of the chlorination of the methane, sulphonation and the sulphation, that is also one of the very important reaction in case of the chemical process industry where, the we need the some of the sulphonated compound.

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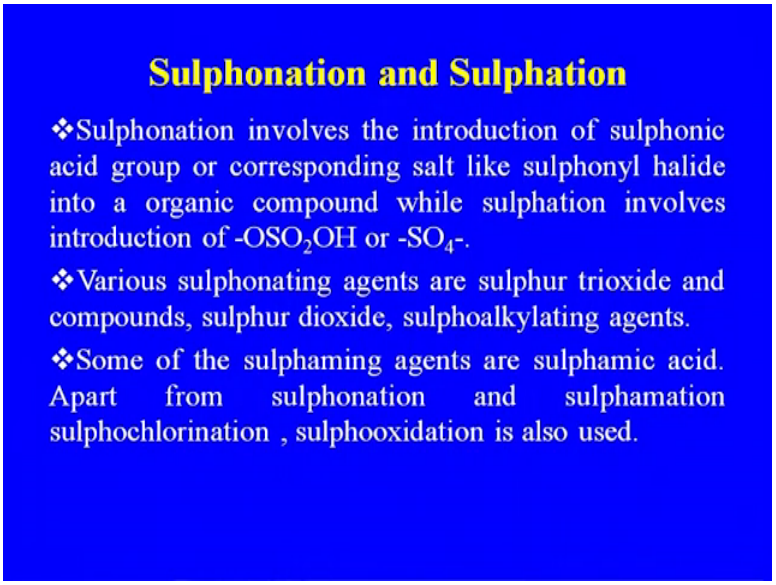

Sulphonation involve the introduction to of sulphuric acid group or the corresponding salt like the sulphonyl halide into a organic compound, while sulphation involves introduction of the OSO 2 OH group or the SO 4 group. Various sumphonatic agents are sulpher trioxide and compounds sulphur dioxide, supho sulphoalkylating agent. Some of the sulphaming agents are sulphamic acid, apart from the sulphonation and sulphamation, sulphochlorination, sulphodiox oxidation is also being used.

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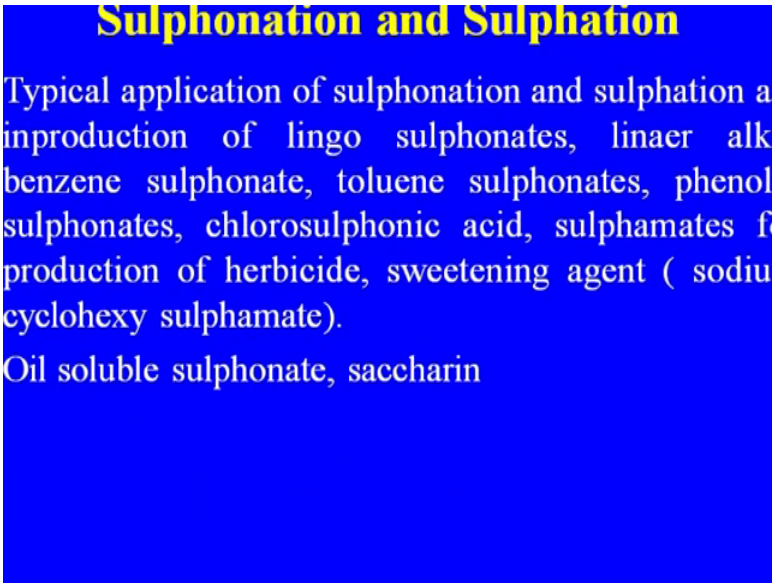

Typical example of the sulphonation in the sulphation or the production of the lignosulphates where, the it is very important because, the lignite we are getting from the paper industry, that we can the lignite that separating during the pulping process. In that lignite, that can be used for the manufacture of lignosulphate, toluene sulphonates, phenolic sulphonates, chlorosulphonic acid, sulphamates, production of herbicide, sweetening agent, oil soluble sulphonate and the saccharin.

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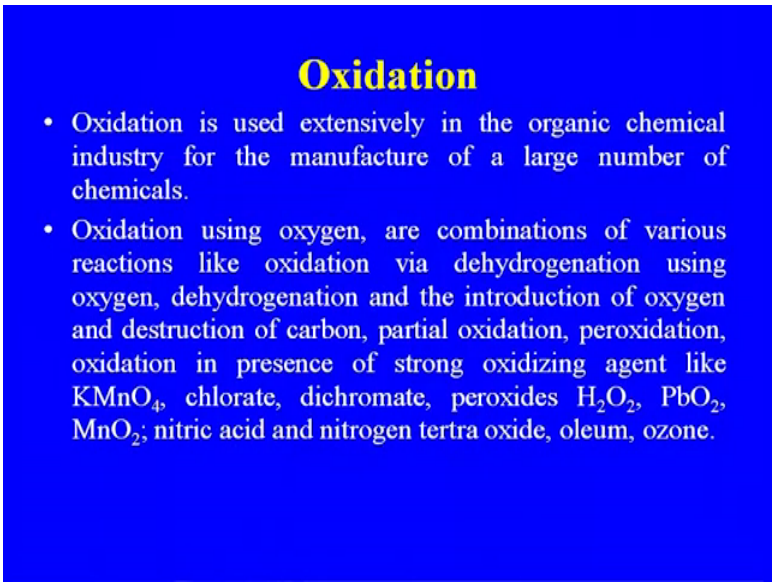

This is the typical example of the sulphur, that we are using in case of the preparation of the sulphamic acid the saccharin sorry. Oxidation, again oxidation that is important reaction in case of the any chemical process industry in the various stage. Just one typical example ethylene, from ethylene to ethylene oxide where, oxidation of ethylene that is (( )).

So, oxidation is used extensively in the organic chemical industry for the manufacture of large number of the chemicals. Oxidation using oxygen or combination of the various reactions like oxidation via dehydrogenation using oxygen and dehydrogenation, and the introduction of oxygen and distraction of the carbon, partial oxidation, peroxidation, oxidation in presence of a strong oxidizing agent, chlorate, dichromate, peroxides hydrogen peroxide.

All these thing that is the some of the additional actually, the agent that may be there during the oxidation along with the oxygen. Oxyoxidation, partial oxidation that is one of the very important process in case of the oxidation of the coal oxidation of the heavier residues you are getting from the petroleum products for the manufacture of the synthesis gas. And that extensively, that is being used in in the chemical process industry, petroleum, refinery, fertilizer industry.

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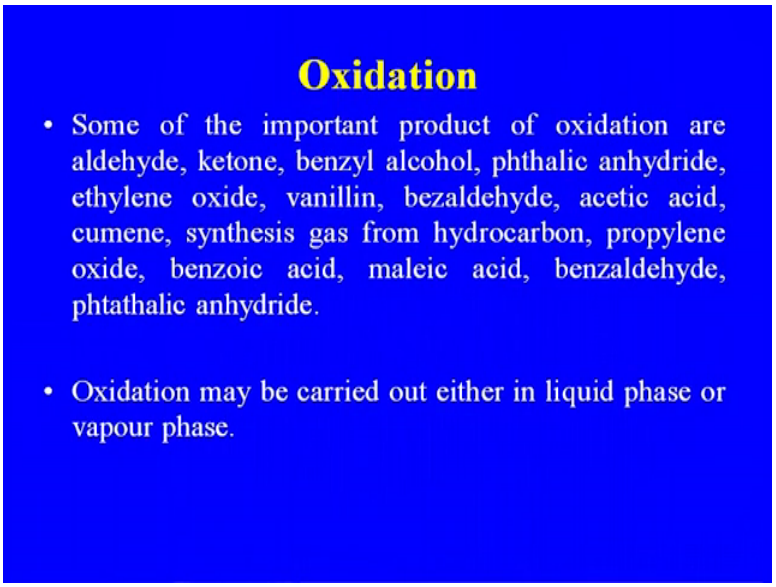

Some of the important product of the oxidation are aldehyde, ketone, benzyl alcohol, phthalic anhydride, ethylene oxide, vanillin, benzaldehyde, acetic acid, cumene,

synthesis gas from hydrocarbons, propylene oxide, benzoic acid, maleic acid, benzyldehyde, phthalic anhydride and so on. Oxidation may be carried out either in liquid phase or the vapour phase.

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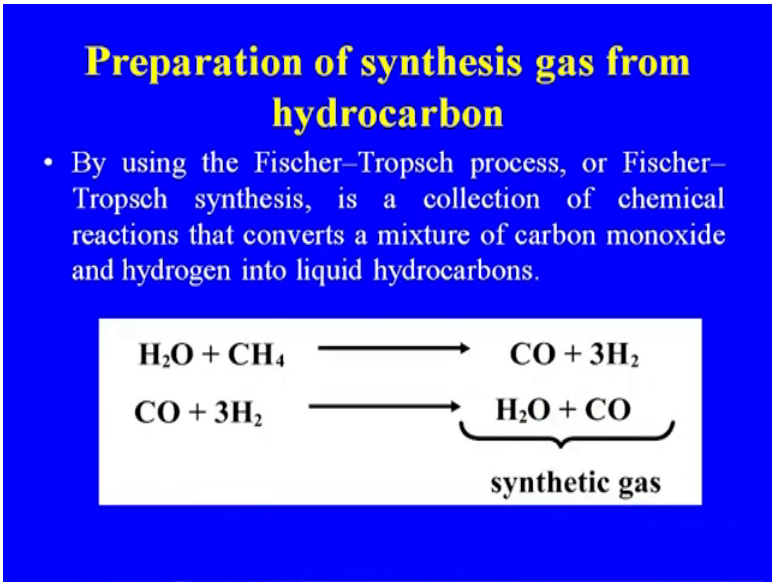

This is a typical example of the synthesis gas from the hydro carbon and that is taking place by the Fischer Tropsch reaction.

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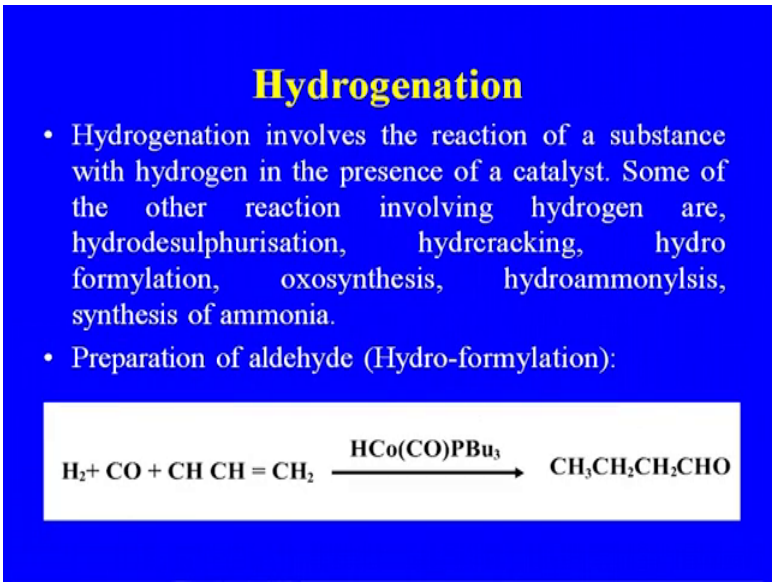

Hydrogenation, that is also one of the very important reaction and involves the reaction of a substance with hydrogen in the presence of a catalyst. Some of the other reaction

involving hydrogen are hydrodesulphization in the process, which we are using in case of the petroleum refinery. Hydrocracking, again in case of the petroleum refinery now, we are using hydrocracking along with the fluidized bed catalytic cracking for the cracking of the heavier residues, you are getting from the atmospheric column or the light gas oil from the distillation. Hydroformylation, oxosynthesis, hydroammonylsis and the synthesis of the ammonia.

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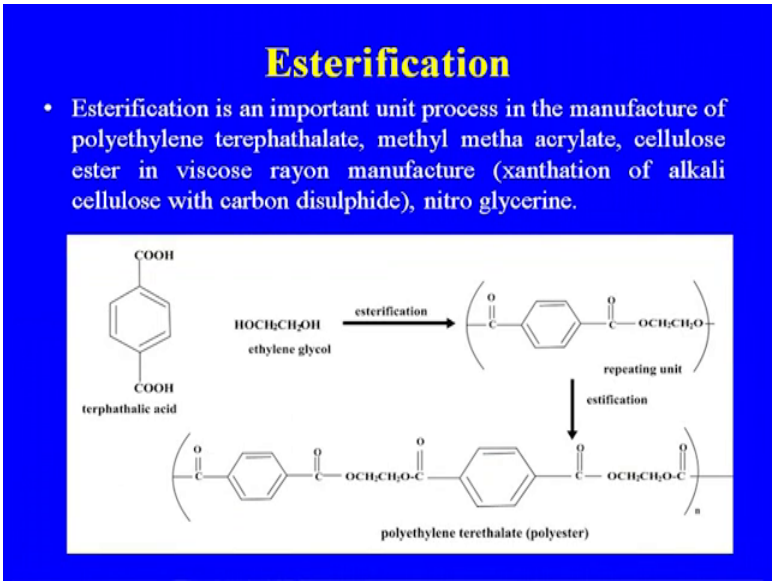

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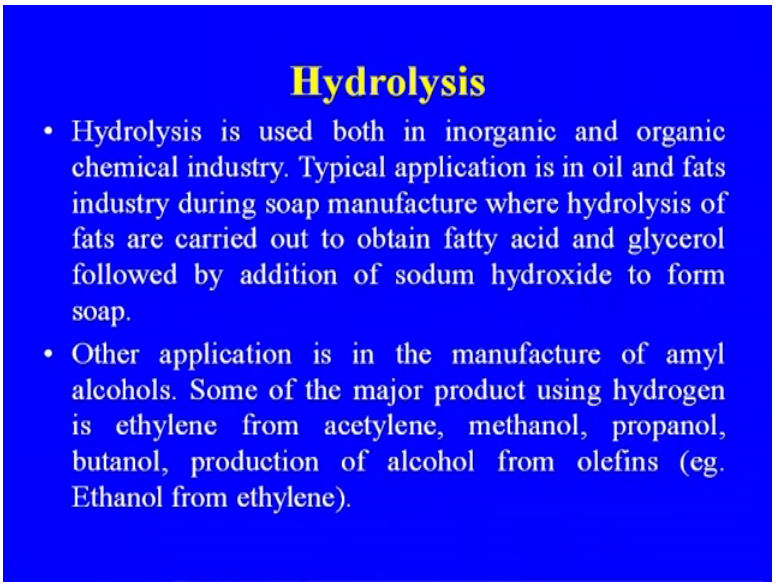

Esterfication is an important unit process in the manufacture of polyethylene terephathalate, methyl metha acrylate, cellulose ester in viscose rayon manufacture nitro glycerine.

Hydrolysis is used both in inorganic and organic chemical industry, typical application is in oil and fat industry during soap manufacture. Hydrolysis of fats are carried out to obtain the fatty acid and glycerol followed by addition of sodium hydroxide to form, this is the process we are using in the case of the soap manufacture. Other application is in the manufacture of amyl alcohol, some of the major products which we are getting from the hydrolysis using hydrogen is ethylene from acetylene, methanol, propanol, butanol, production of alcohol from olefins, etcetera.

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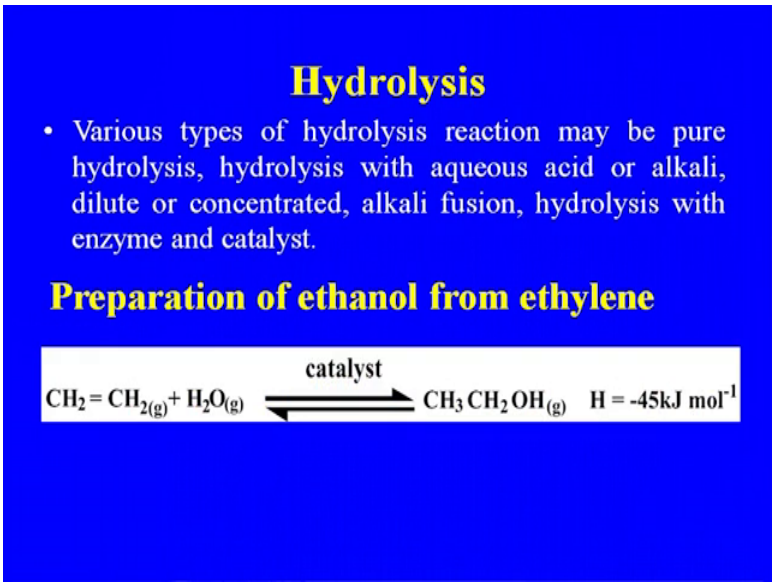

Various type of the hydrolysis reaction may be pure hydrolysis, hydrolysis with aqueous acid or alkali, dilute or concentrated, alkali fusion hydrolysis with enzyme and catalyst. This is the typical reaction in case of the preparation of the ethanol from the ethylene because, the for the ethylene there are two route, one is the from the ethanol route another is from the ethylene route. So, from the ethylene route, that we are getting by this reaction, the ethylene.

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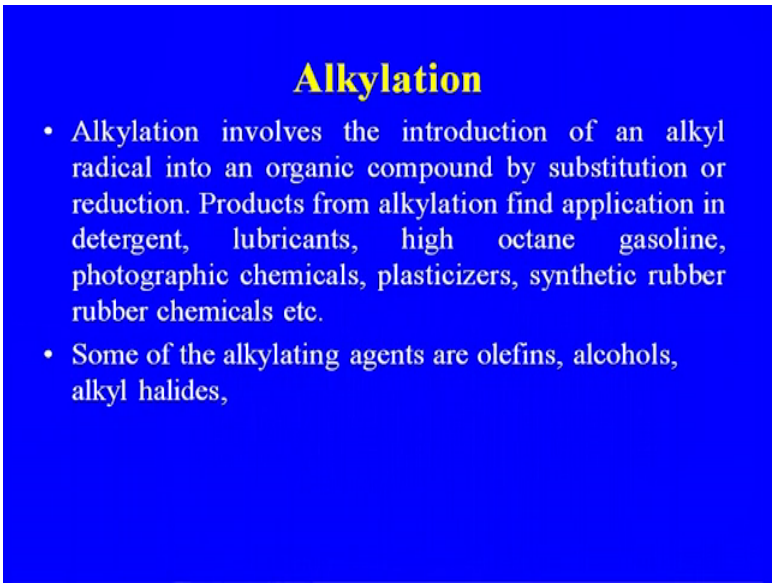

Alkylation, alkylation involve the introduction of an alkyl radical into an organic compound by substitution or the reduction. Products from alkylation find, while application in detergent, lubricants, high octane gasoline, photographic chemicals, plasticizers, synthetic rubber chemical. Some of the alkylating agents are olefins, alcohols, alkyl halides, here actually in case of the alkyl alkylation process, that is now we are using in case of the petroleum refinery and the petrochemical industry.

Both alkylation for producing the high octane gasoline and the in case of the petrochemical urea for the manufacture of the linear alkyl benzene where, the alkylation process find the alkylation of the benzene with the one alkyl group, that we are getting the linear alkyl benzene. There has been lot of the changes in the alkylation process regarding the catalyst because, the sulphuric acid and the phosphuric acid were commonly used as catalyst in alkylation process here.

But, in case of the sulphuric, if you compare sulphuric acid and phosphuric acid, phosphoric acid consume less acid in comparison to sulphuric acid. And that was the reason why, the alkylation process that was shifted from sulphuric acid to phosphuric acid. But, the still in case of the sulphuric, this phosphuric acid and sulphuric acid both lot of the corrosion problem was there. And now, the new development in case of the alkylation process, that has been to go for the solid acid catalyst, that was because of the your corrosion problem.

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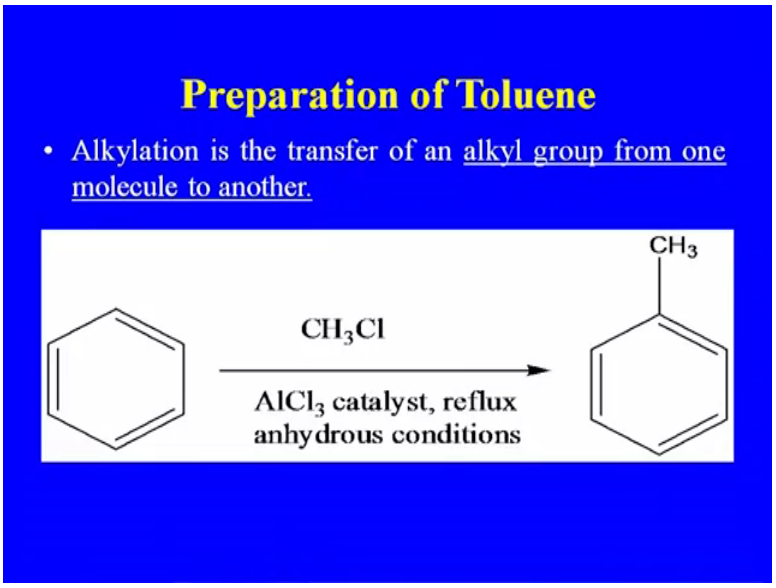

Preparation of the toluene, alkylation that may be from the benzene to toluene, although this is not very common process but, you can get the toluene from the benzene. Polymerization reaction because, you see the polymerization at the same time, (()) these are the some of the the polymerization reaction, that is taking place and they are very important in case of the manufacture especially, the polymer, synthetic fiber, synthetic rubber.

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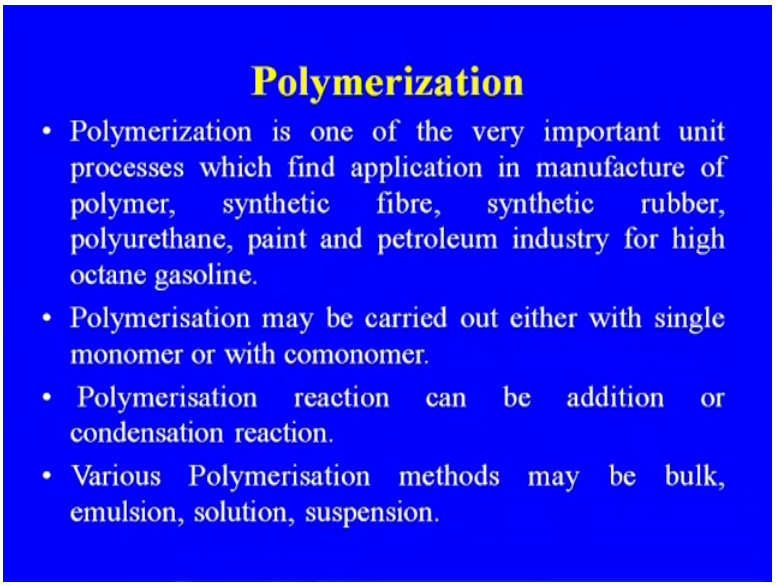

Polymerization may be carried out in either with single monomer or with the comonomer because, incase of the polyethylene, we are using some comonomer also, vinyl fibers also. Some time the vinyl chloride, that is being add as a comonomer in manufacturing some of the fiber in so, it may be monomer or the comonomer, both that is being. Polymerization reaction can be addition or the condensation reaction, various polymerization methods may be bulk emulsion solution or suspension polymerization.

Any of the these process, that is being used depending upon the requirement of the process, these are the some of the major products which you are getting through the polymerization.

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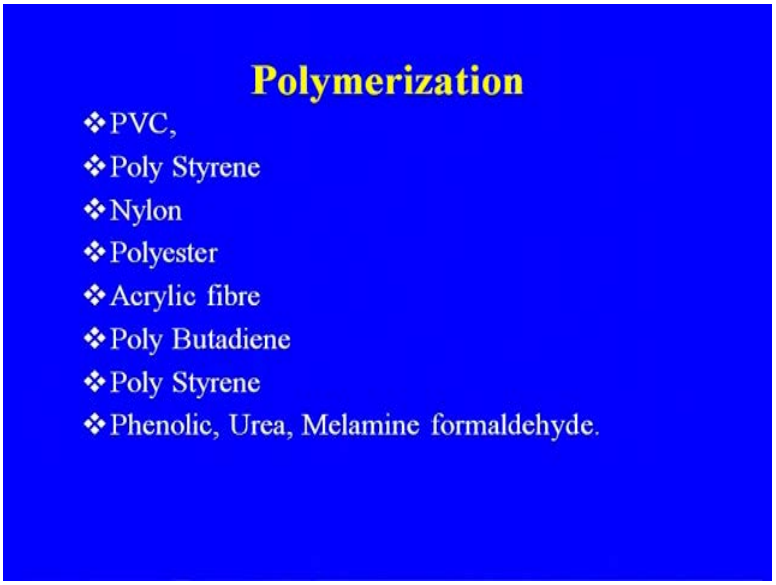

PVC, Poly styrene, nylon, both the nylon 6 and nylon 66, polyester from the terephthalic acid, acrylic fiber that we are getting from the polymerization of the acryonitrile, poly butadiene, poly butadiene that we are because, this is the butadiene that is available from the steam cracker. So, instead of going for the manufacture, many of the plants which are having the naphtha cracker, they are making the poly butadiene.

Polystyrene, urea, various actually the phenolic, reason that you can see the urea, melamine, phenolic, phenol formaldehyde. These are the some of the other reason, that we are making thermo that is not the phenalic but, the phenolic urea and the melamine, formaldehyde.

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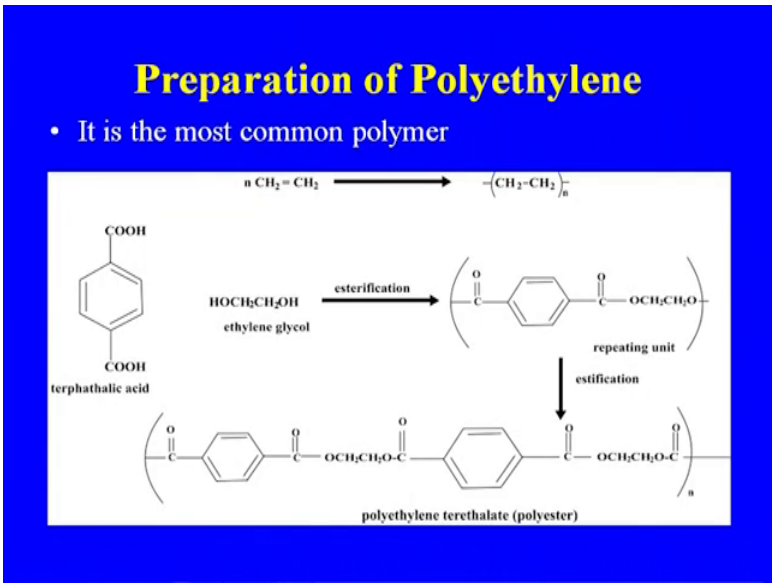

This is the typical, actually the reaction that is taking place in case of the polythene, polyethylene, in case of the polyethylene, we are sometimes we are using the butane 1 as a also as a comonomer. Now, we come to because, we discussed about the unit process now, the unit process by the unit various unit process, various reaction we were able to produce some product.

But, how to separate it, that was a major challenge during the initial stage of coming of the chemical process industry. Because, all these processes now you are seeing in case of the unit operations, were not well developed. So, the problem was then the separation to get the good quality, better quality of the product and the better separation. So, and at the same time, to just to improve the productivity through the lesser energy consumption.

These were the some of the issues earlier and the how, the evolution of the chemical engineering that took place. That was the reason, how the from the chemistry to chem industrial chemistry, industrial chemistry to chemical technology. And then the finally, it was the in the end of the controlling the chemical industry, that came to the chemical engineering.

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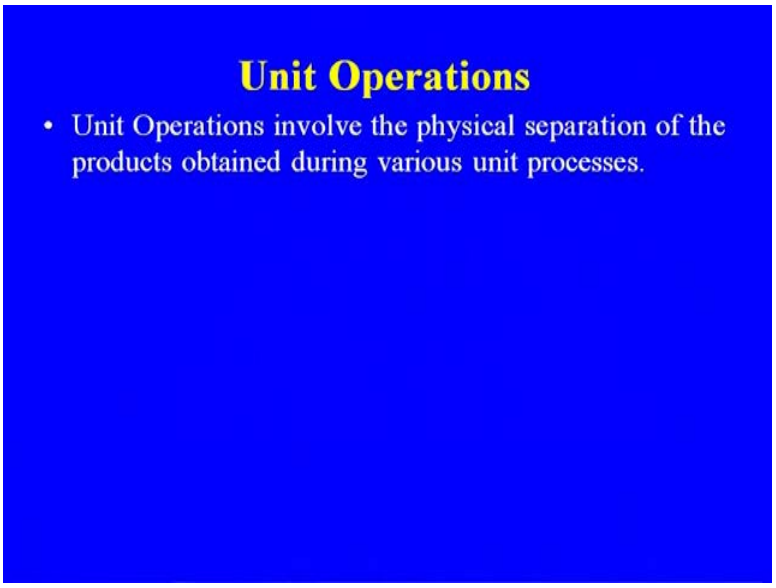

So, unit operations involve the physical separation of the products obtained during the various unit processes. Large number of the unit operations are there, which are being used in the chemical process industry, in petroleum refinery, petro chemical industry.

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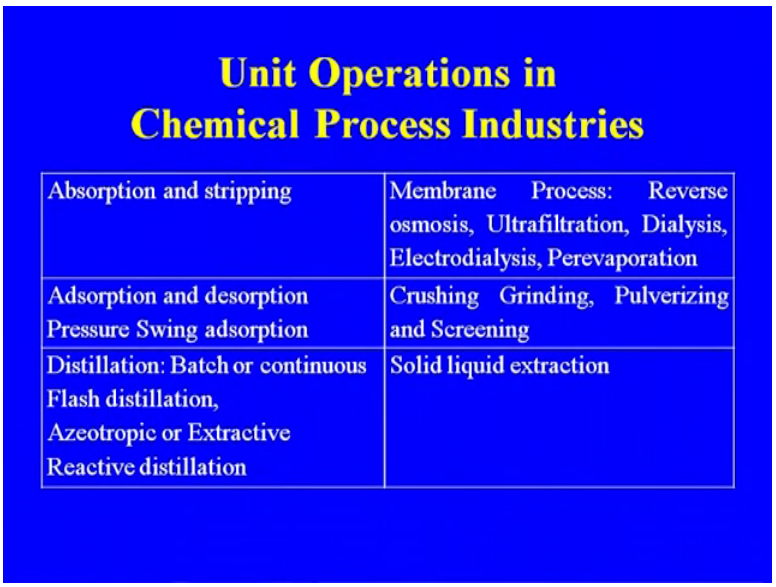

First one of the very common actually, the unit operation which was there, that is absorption and stripping. Adsorption, desorption, pressure swing adsorption, that was the development in case of the adsorption the. And now, the whatever the separation of the air, that is possible because, earlier we used to have the liquifiaction of the air first and

getting the oxygen, nitrogen. Now, with the coming of the pressure swing adsorption, we are able to produce oxygen, nitrogen even at a lower capacity.

Distillation, that may be the batch or the continuous, flash distillation, azeotropic or extractive and the newer development is the reactive distillation where, the simultaneous reaction and the distillation, both are taking place. Membrane process, membrane although the membrane or the filteration, that was the from very beginning that was being used. But, the real development that came, when the problem of the your purification of the sea water, how to get the drinking water or the process, water from the sea water.

So, the major development was because of that but now, the membrane process which are the various type of the membrane process that has been developed. Reverse osmosis, ultrafiltration, dialysis, electrodylysis, perevaporation, all those process that has been developed and that is being used. One of the another example of the membrane process, that was the coming of the caustic chlorine plant based on the membrane process because, earlier we are using the diaphragm cell process, diaphragm it was shifted to the mercury cell process.

Because, some advantage of the mercury cell process was there but again, the mercury pollution problem, because of the mercury now, the all the caustic chlorine plant they are based on the membrane process. Then, the another important unit operation that is the specially, in case of the mineral industry, cement industry, refractory that is the crushing, grinding, pulverizing and screening.

Because, these are the some of the very initial stages especially, in case of this, you take the case of the cement industry, lot of the changes that has taken place in case of the unit operation for the crushing or the pulverizing. Earlier, the boiler we were using the non polarized core now, we are using because, high capacity boilers are there now, we are using the pulverized core.

in case of the cement manufacture, we are having the crushing and grinding, earlier we used to have the ball mill grinding now, we are having the vertical roll mill at the place load. Then, the solid liquid extraction, some of the other separation process unit, that is part of the unit operation that is the evaporation.

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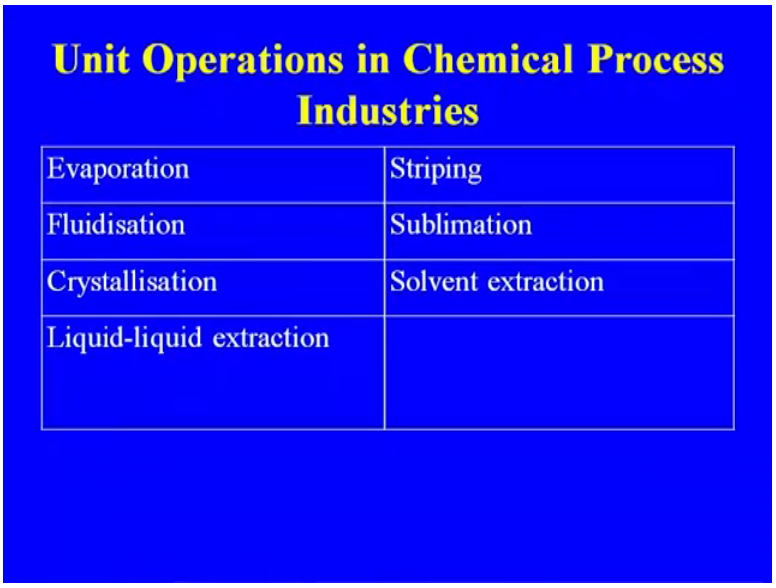

Fluidization, that was the how, the from the fixed bed to fluidized bed, moving bed that came into existence. Crystallization, liquid liquid extraction, even in the crystallization and liquid liquid extraction that is being used in extensively, in case of the petroleum and petrochemical industry. In case of the petroleum, when you are separating the your close boiling point component that is the paraphene, from the aromatic we are using the liquid liquid extraction for the separation of the paraxylene, We are using the crystallization process, stripping.

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Sublimation, that is another process that we are using in case of the polyster manufacture, not the polyster exactly, that is the your purification of the terephthalic acid, Solvent exraction. now, we will discuss some of the important actually the unit operation that is being used.

Distillation, that is called the king of all the separation process and most widely used in separation technology and will continue as an important process in the future also. Because, you see the if you you cannot imagine a disttila any process, chemical process whether it may be petroleum or the petrochemical, without the distillation column. Because, you are using for this for the separation of the reactant, we are using the distillation.

That is, the distillation process involve the separation of binary mixture or the multicomponent system or the multicomponent mixturising. In case of the crude oil, separation is based on the difference in the boiling point and the relative volatility. Sometimes there is problem in case of when the close boiling point is there but, still there are some development in the distillation process that is, the azeotrpic and extractive distillation and so, we can also process the close boiling components.

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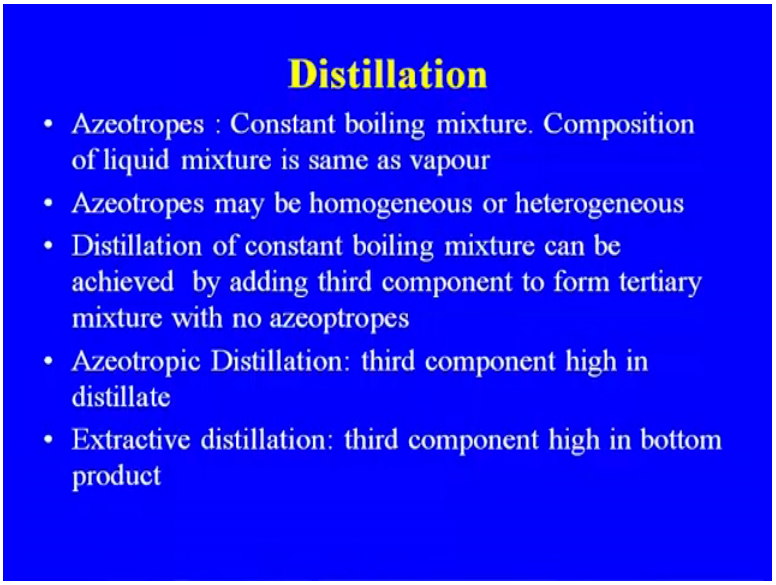

So, this is about the azeotropic, when the constant boiling mixture composition of the liquid mixture is same as vapour and so, the separation is difficult by the conventional distillation. Azeotropes may be homogenous or the hetrogenous, distillation of the

constant boiling mixture can be achieved by adding a third component, that we are using incase of the azeotropic distillation or the extractive distillation to form a tertiary mixture with no azeotrope and so, the separation that becomes easier.

So, azeo why we call it the azeotropic or the extractive distillation, azeotropic in the case of the azeotropic distillation, third component high in the distillate. In case of the extractive, the third component high in the bottom product so, this is the basic difference in case of the. One of the example that you can say, that even in case of the nitric acid where, the after the 55 percent I think, that is about the nitric acid we will have to concentrate by the azeotropic, this is that is the distillation that is involved for removal of the order.

Same thing is happening in case of the alcohol, even in case of the many of the mixture, in case of the refinery, we need the azeotropic distillation or the extractive distillation. So, these are the some of the development that has taken place in case of the distillation.

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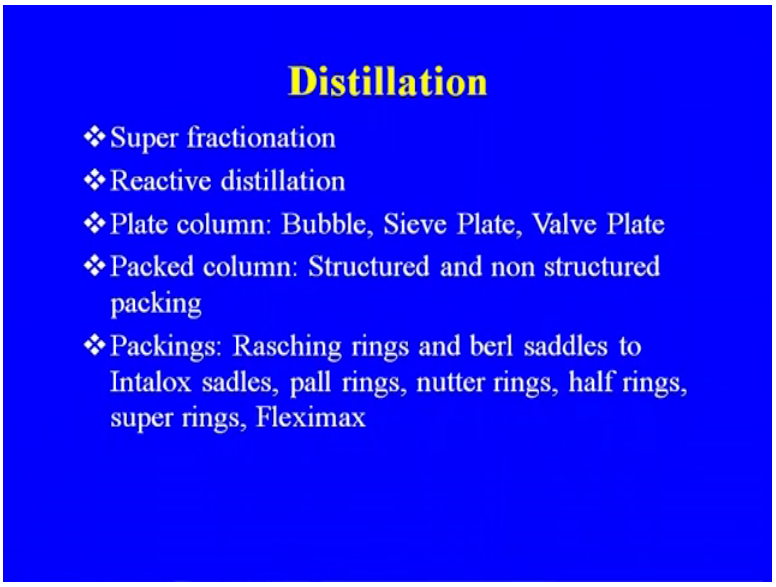

That is, the super fractionation, reactive distillation, plate column, bubble, sieve plate, valve plate. So, these are the some of the in case of the plate column then, the packed column, again in case of the packed column, lot of the development that has taken place. Structure and non structure packing, packings the earlier normally, we are using the rasching rings, berl saddles now, it is the intalox saddles, pall rings, nutter rings, etcetera.

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Distillation used in that as I told you, the earlier also this is being used extensively used in the petroleum refining and petrochemical. We cannot imagine a refinery or the petrochemical complex without a distillation column, it is the heart of the petroleum refining. And all the process required distillation at various stage of whether from the from the (( )) crude oil distillation to the catalytic reforming or it may be FCC for separation of the various product, which are formed during the process we need the distillation, same thing happen in case of the many of the petrochemical process also.

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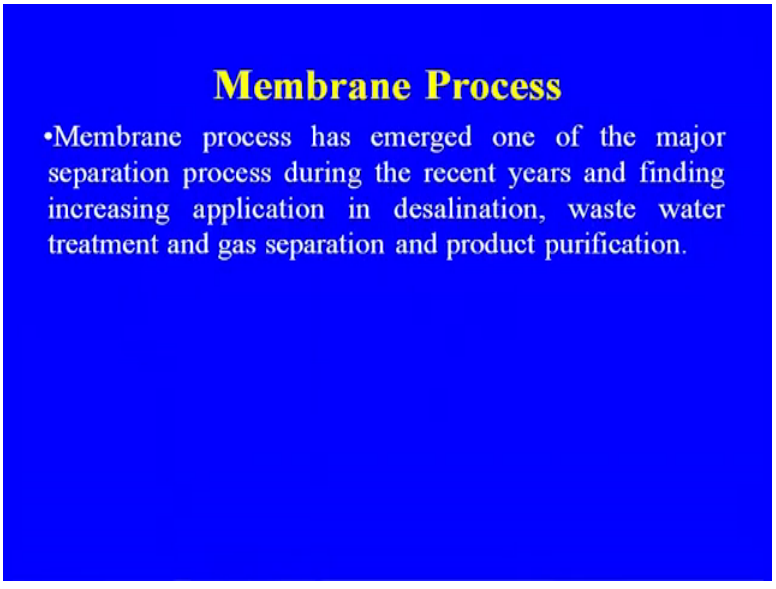

Membrane process have emerged one of the major separation process during the recent years and finding increasing application in the desalination. Because, this was the actually, how the evolution of the membrane process that came, the application in the desalination, waste water treatment. Now, we are using the membrane process in waste water treatment also, gas separation and the product purification. Now, in case of this, separation of the CO 2 from the hydrogen, from the natural gas or from the synthesis gas, membrane process.

Now, the membrane is available, you can go for the separation of the CO 2 from the hydrogen other than the conventional process. So, that is the how, the development that has taken place in case of the membrane process and the product. Only the problem in case of the constant, in case of the membranes process is the, your choking of the membrane, cost of the membrane but, there they are in continuous development in case of the membrane also to improve the cost.

Improve the cost means, the lower cost of production that may be for the membrane so, the now extensively, we are using the membrane process. Already I told you, that is the in caustic chlorine manufacture, one was the major application of the membrane process in the caustic chlorine. Even in case of the petrochemical process, that we are using the membrane process.

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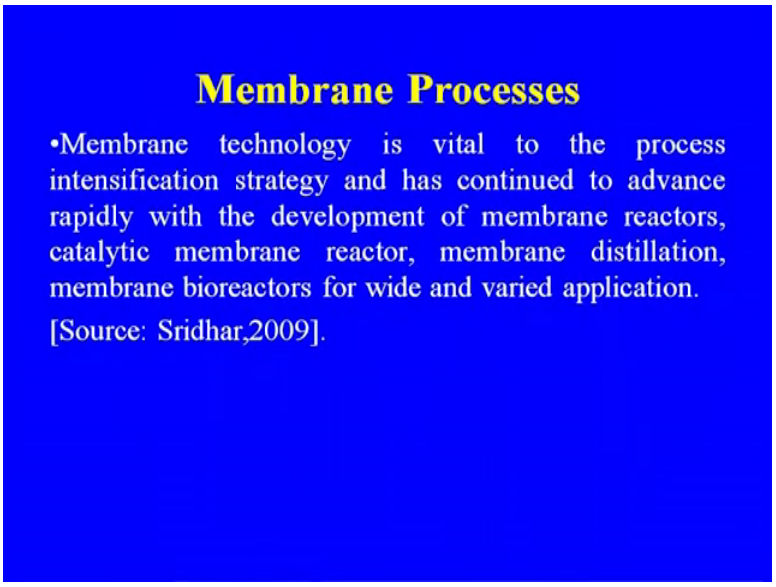

Membrane technology is the vital to the process intensification, strategy and has continued to advance rapidly with the development of the membrane reactor. Now, we are talking about the membrane reactor also, catalytic membrane reactor, membrane distillation also. Now, we are talking about the, these are the some of the new development, membrane bio reactors for wide and varied application.

Now, we will be discussing about the various membrane process, as I told you there has been continuous development in case of the membrane process. And so, now, we are having a large number of the membrane processes where, the driving forces that is different.

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Membrane Process and Driving Force

Membrane process	Driving force
Reverse osmosis	Pressure difference
Ultrafiltration	Pressure difference
Microfiltration	Pressure difference
Nanofiltration	Pressure difference
Dialysis	Concentration difference
Pervaporation	Concentration difference
Liquid membrane	Concentration difference
Electro dialysis	Electrical potential
Gas Permeation	Concentration difference
Thermo-osmosis	Temperature difference

That is the, first actually the reverse osmosis, ultrafiltration that has been used from very beginning and so, the here the driving force is the pressure difference. Microfiltration, nanofiltration in all these process, the pressure difference is the driving force, dialysis is the concentration difference. Perevaporation concentration difference, liquid membrane concentration difference, electro dialysis the electrical potential is the driving force and gas permeation concentration difference.

Thermo osmosis is the temperature difference, that is the driving force so, these are the various type of the membrane separation process, which we are using in some or other form in the chemical industry.

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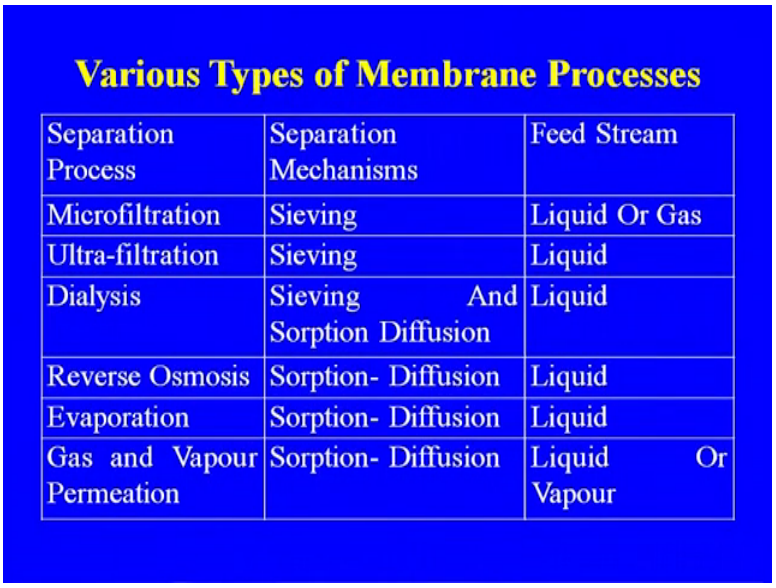

The various type of the membrane process, again the what are the separation mechanism and the feed stream. Micro filtration sieving, ultra filtration sieving, liquid or gas, liquid dialysis, liquid, reverse osmosis liquid, evaporation liquid, gas and vapour permeation liquid vapour. So, these are the various type of the membrane processes that is being used.

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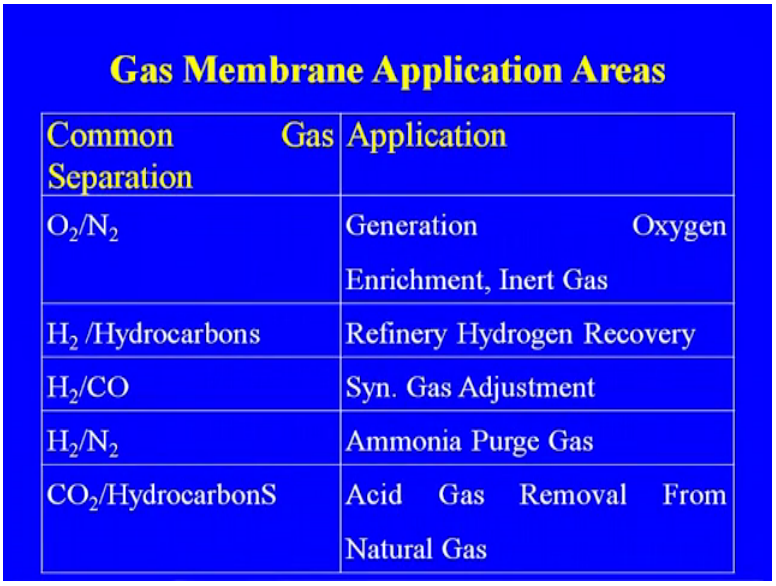

Gas membrane application area, as I told you earlier also, we are using a membrane not it is not only limited to desalination process or the caustic chlorine manufacture. Now, the it is finding application in the chemical industry in for the other purpose also.

Just like, you can see the one of the oxygen nitrogen generation of the oxygen, enrichment, inert gas. Hydrogen, hydrocarbons refinery and hydrogen recovery, H 2 and CO synthesis gas adjustment, hydrogen nitrogen ammonia purge gas, CO 2 hydrocarbons acid gas removal from the natural gas. These are the some of the process, that we are using in the even in refinery.

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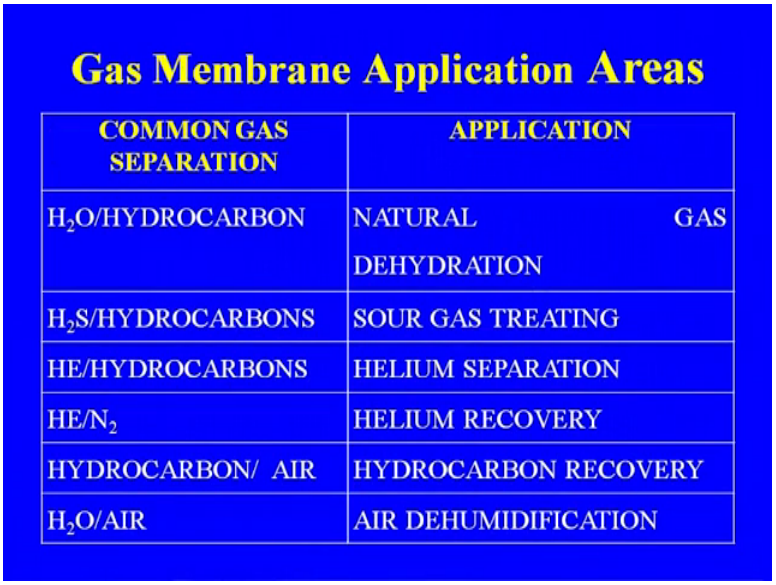

Some of the process that being H 2 O hydrocarbon natural dehydration natural gas dehydration or the because, the your presence of the moisture that create lot of problem in case of the natural gas and that has to be removed so, this process that can be used. H 2 S hydrocarbon for sour gas treating means, the sweeting of the sour gases, that you can use the membrane process.

Helium hydrocarbons helium separation, helium nitrogen helium recovery, hyrdrocarbon air hydrocarbon recovery, hydrogen air for the air dehumidification. Another process as I told you, the absorption from very beginning, that has been some or other form that that is being used in the chemical process industry.

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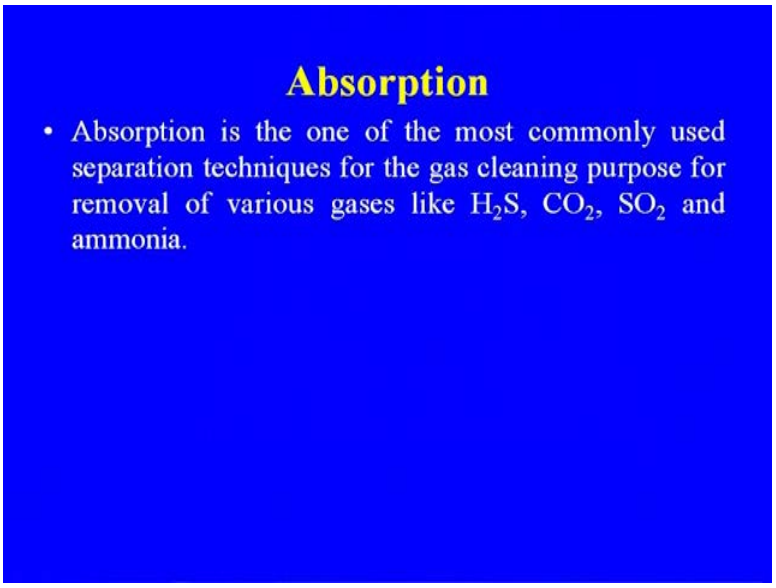

That is one of the most commonly used separation techniques for the gas cleaning purpose, for the removal of the various gases like H 2 S, CO 2, SO 2, ammonia. And even for the chlorine, that we are using some of the absorbent for absorbing these gases for removal. Even in the process industry suppose, the in the manufacture of the ammonium hydroxide, in the manufacture of the sulphuric acid or in the manufacture of oleum, we are using the absorption process.

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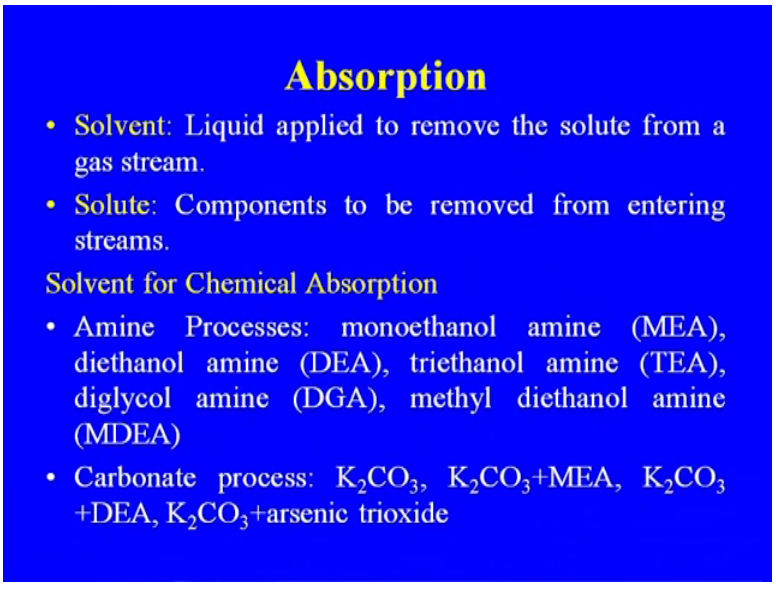

So, it is not from the but, from the environmental point of view, the absorption process that is very important but at the same time, it is also very important in many of the chemical process industry. Solvent because, two parts are there in case of the, one is the solvent, another is solute, which is to be removed from the gas stream.

So, liquid applied to remove the solute from a gas stream, components to be removed from the entering the stream, solvent various solvent that has been because, there has been continuous development in case of the solvent also. Now, the amines, they are very mono MEA, DEA DiEthanol Amine or the triethanol amine, di diethylene glycol amine or methyl diethanol amine. So, some of the actually, the amine solvents now that is being extensively used in even in case of the refining also.

The carbon carbonate process K2 CO 3, that was the one of the oldest actually the absorbing media, that was being used for absorbing the CO 2 during the ammonium paraoxide. Now, it has in many of the places that has been replaced with the MEA or it may with the methanol and various combination of the potassium carbon because, that process of the CO 2 absorption, highly corrosive atmosphere is there. So, we are using some of the corrosion invator and so, the some of the corrosion invators, they are they have been added here, arsenic dioxide that is one of the corrosion invator.

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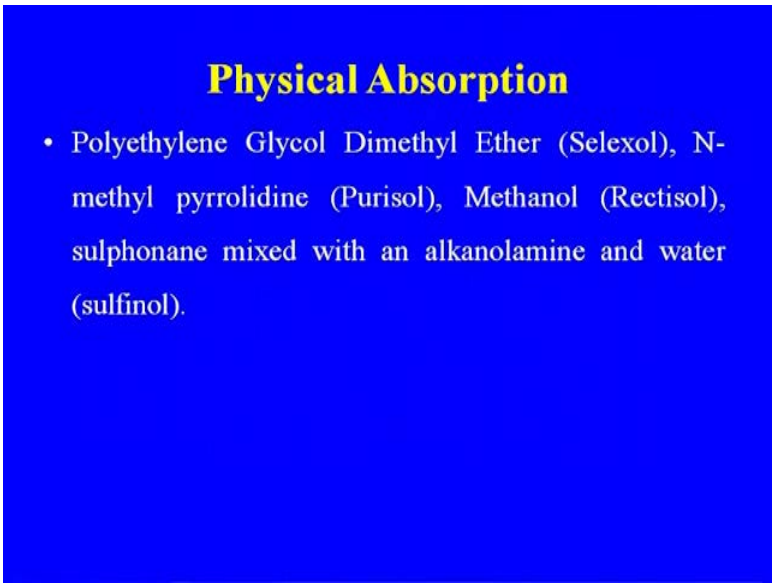

Physical absorption, polyethylene glycol, dimethyl ether and MP methanol sulphonane mixed with an alkanolamine and the water (()). Another development in case of the separation process, that has been the adsorption that is the physical.

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Adsorption technology now used very effectively, that was earlier for the carbon adsorption, that is one of the very common process use of the activated carbon in case of the purification of the water from. In the ancient time, charcoal that was being used for the cleaning of the (()), even in case of the perpurification of the water, that has become a very important separation process in case of the petrochemical industry, for the separation of the many gas and a liquid mixture, in the petrochemical industry, bio chemical industry.

And as I told you, the for the environmental pollution control in the case of the treatment plant and is often a much cheaper and easier option than distillation, absorption or the extraction. Some of the commercial adsorbent are the silica gel, activated carbon, carbon molecular sieve, charcoal, zeolites molecular sieves, polymer and resins, clays, biosorbents. So, these are the some of the commercially available, because of the coming of the molecular sieve, there has been lot of the application of the adsorption process. Even adsorption and the pressure swing adsorption, that is being used in case of the separation of the many many chemicals in case of the petroleum and the petrochemical industry.

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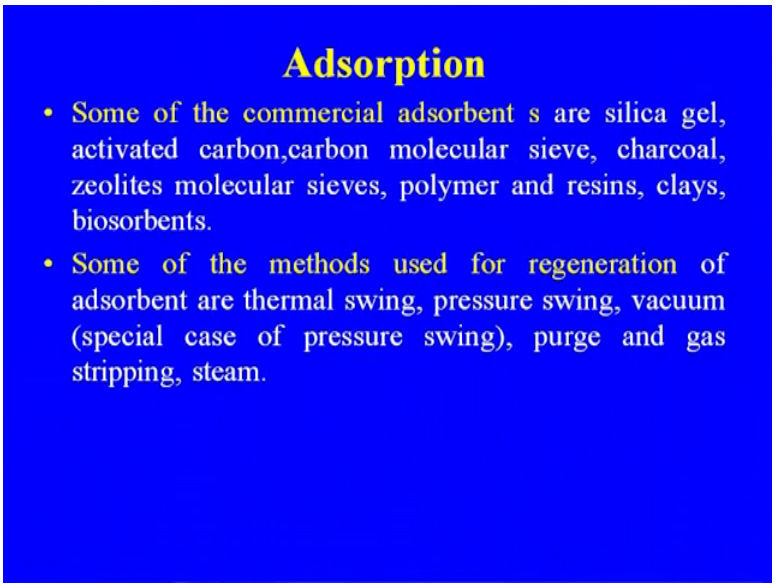

One of the because, you see the some of the methods used for the regeneration, before going to the application of the adsorb various adsorption process in the chemical and the petrochemical industry. Let me discuss about the gen regeneration because, the regeneration that is very important in case of the adsorption. Like the in case of the catalyst, if you are using, you will have to regenerate. Here also, the regeneration that is very important and the for the generation of the adsorption, we are using the thermal swing, pressure swing, vacuum.

So, pressure swing adsorption where, we are increasing the pressure, reducing the pressure and so, disorption is taking place. So, pressure swing adsorption this is the why, it is called the pressure swing adsorption, that will be used for the separation of the oxygen and nitrogen and even in case of the paraxylene. Purge and the gas stripping steam, these are the some of the commercial processes, which are being used in case of the petrochemical industry.

Parex for the separation of the paraxylene from mixed C 8 aromatic isomers then, the MX sorbex meta xylene from mixed C 8 aromatics, molex process that we are using in case of the manufacture of the linear linear paraffins from branched and cyclic hydrocarbon. Olex process that is from the because, some of the olefins they are having the closed boiling point especially, when we are separating the C 4 components from the

FCC gasses or the steam. So, for the separation of the close boiling olefins, the olex process that is being used.

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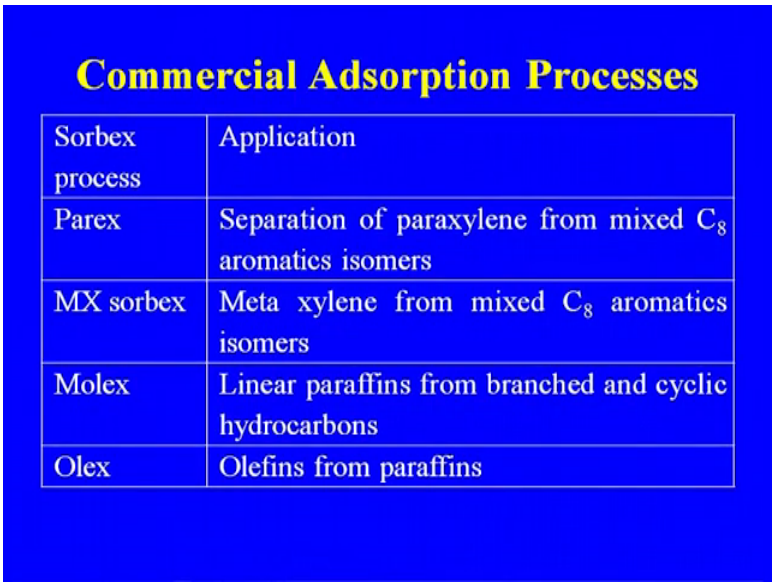

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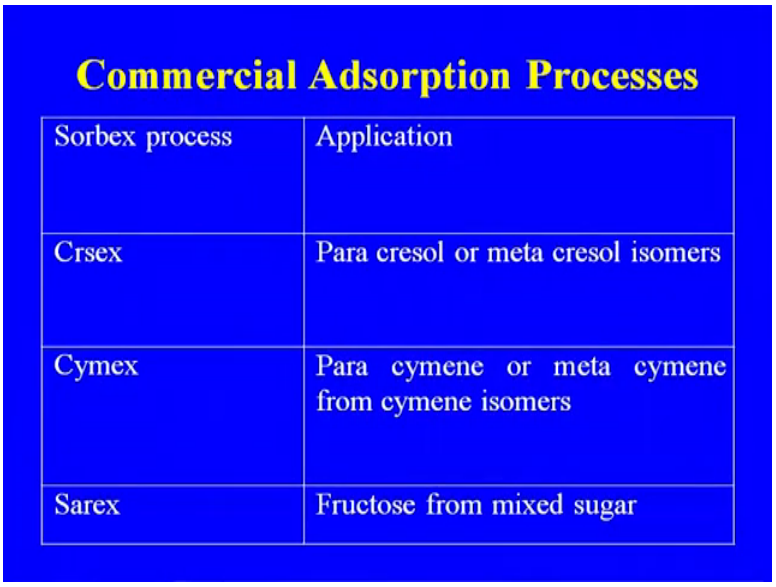

Crsex para cresol, cymex for separation of the paracymene, sarex for the fructose, these are the other some of the other application of the adsorption process.

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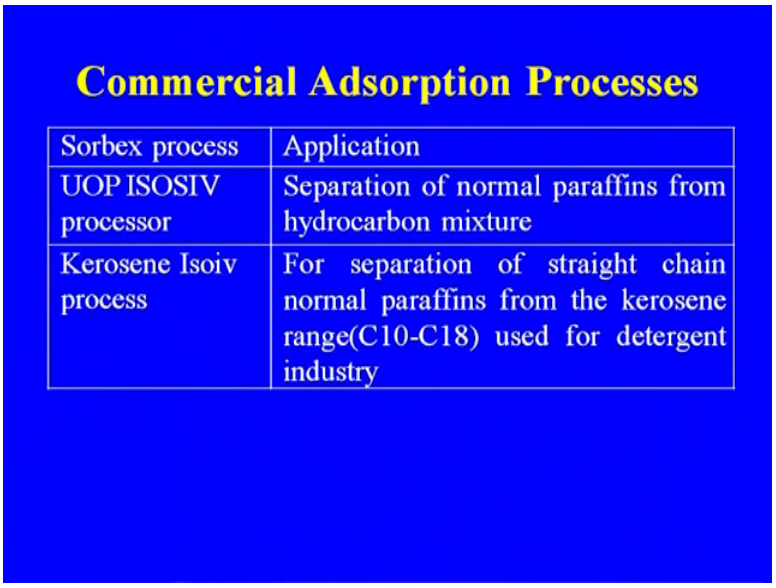

This is the one of the adsorbent that is been developed by UOP for the separation of the normal paraffins from the hydrocarbon mixture. Kerosene Isoiv process for the separation of straight chain, normal paraffin from the kerosene range used for the detergent industry.

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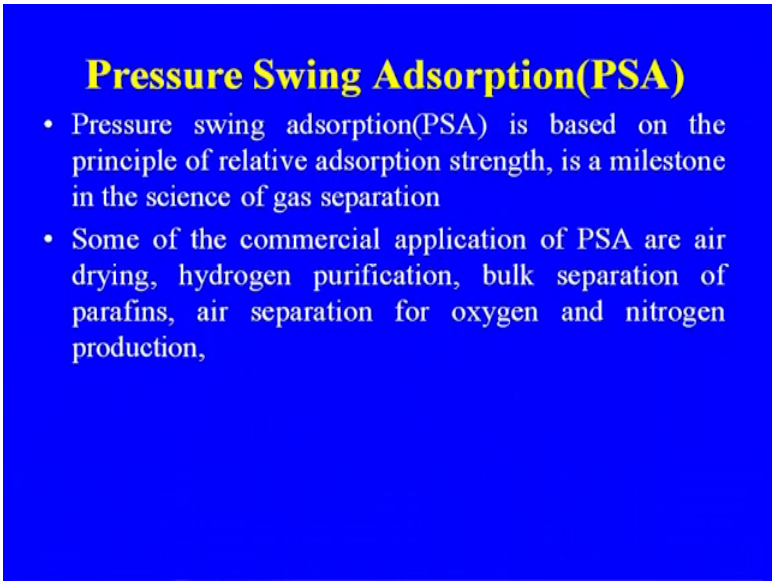

Pressure swing adsorption as I told you, that is that is being used in the chemical industry based on the principle of relative adsorption strength, is a milestone in the science of the gas and separation. Some of the commercial application of the PSA are air drying,

hydrogen purification, bulk separation of the paraffins, air separation for oxygen nitrogen production.

Crystallization process, crystallization process earlier it was only limited to the sugar industry, when the crystallization of the sugar and we are separating the molasses from sugar. But now, it has come in a big way in separation of the some of the close boiling point especially, in the case of the separation of the paraxylene from the xylene steep.

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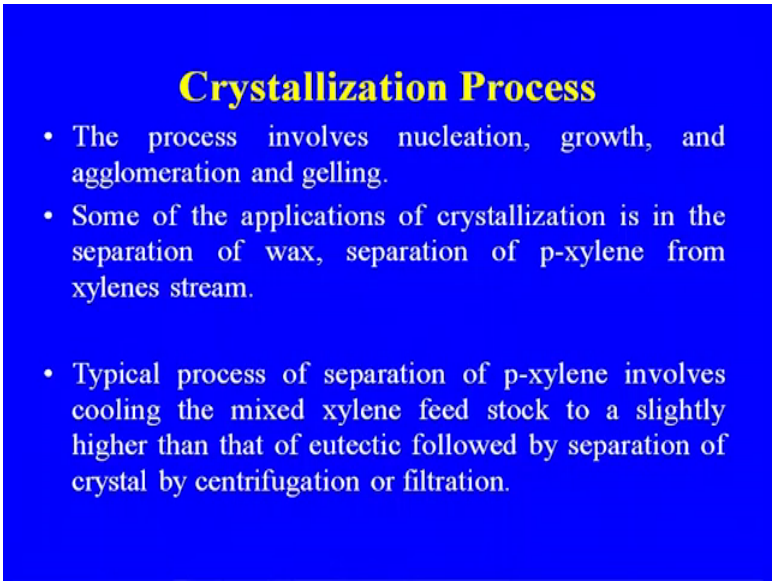

The process involves nucleation, growth and the agglomeration and the gelling, typical process of the separation of the paraxylene involves cooling the mixed xylene feed stock to a slightly higher than that of the eutectic followed by the separation of the crystal by centrifugation or the filtration. So, this is the process extensively, that is being used because, there we are having the two process for the separation of the paraxylene, one is based on the adsorption, another is based on the crystallization.

Liquid liquid extraction because, you see the liquid liquid extraction again it is being very commonly used in petroleum and petrochemical industry for separation of the close boiling hydrocarbons. Some of the major application of the liquid liquid extraction are removal of the sulphur compound from the liquid hydrocarbon, recovery of the aromatics from liquid hydrocarbon, separation of butadiene from C 4 hydro because, here also, the same problem is the close boiling point.

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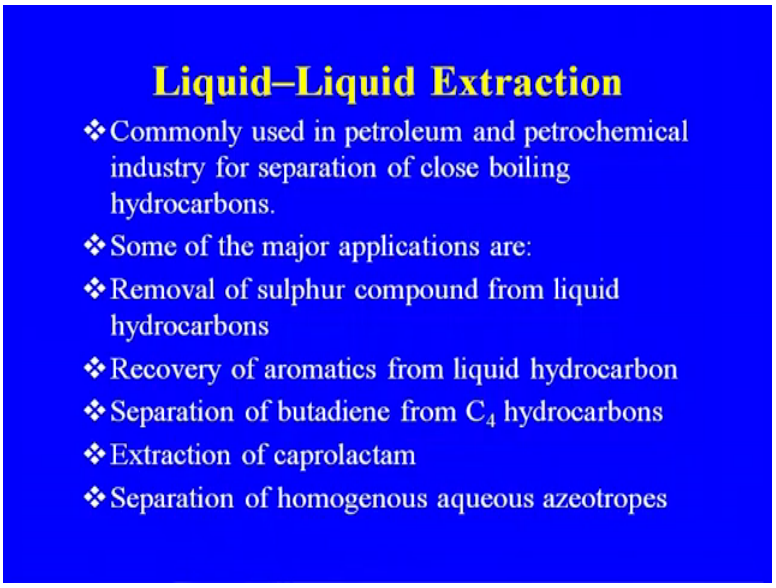

Components are there and so, the we are separating by liquid liquid extraction, extraction of the caprolactam, separation of the homogenous aqueous azeotropes where, this liquid liquid section and there has been continuous development in case of the solvent that is being used. Now, the n m p sulphonate, dimethyl formalyte these are the some of the solvent, which has been developed and finding wide application because, earlier we used to have the phenol. We used to have (()) these where, the some of the solvent that was being used.

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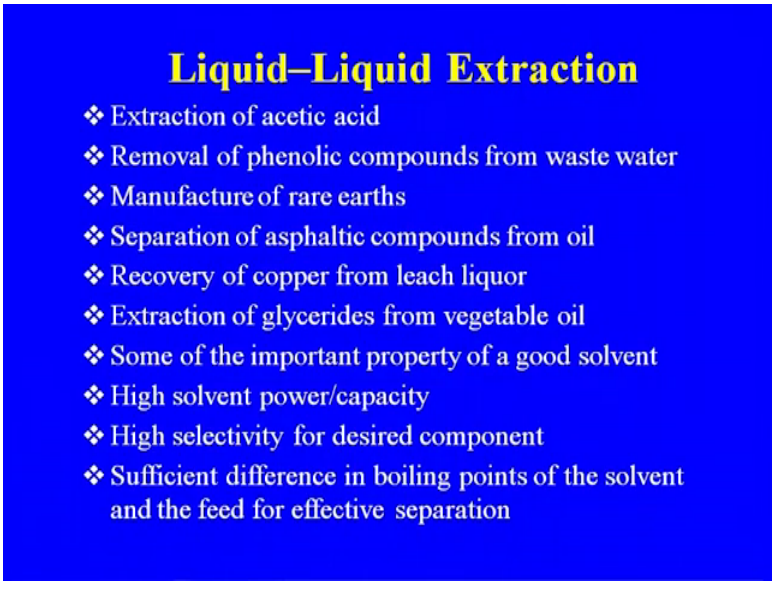

Other application of the liquid liquid extraction are extraction of the acetic acid, removal of the phenolic compounds from waste water, manufacturing of rare earths, separation of the asphaltic compounds from oil, recovery of the copper from leach liquor, extraction of the glycerides from vegetable oil. Some of the important property for the good solvent because, the price of the solvent that is also very important.

High solvent power capacity, high selectivity for desired component, sufficient difference in the boiling points of the solvent and the feed because, you will have to strip the solvent from the product. And so, the separation only it will be possible when the there is sufficient difference in the boiling point.

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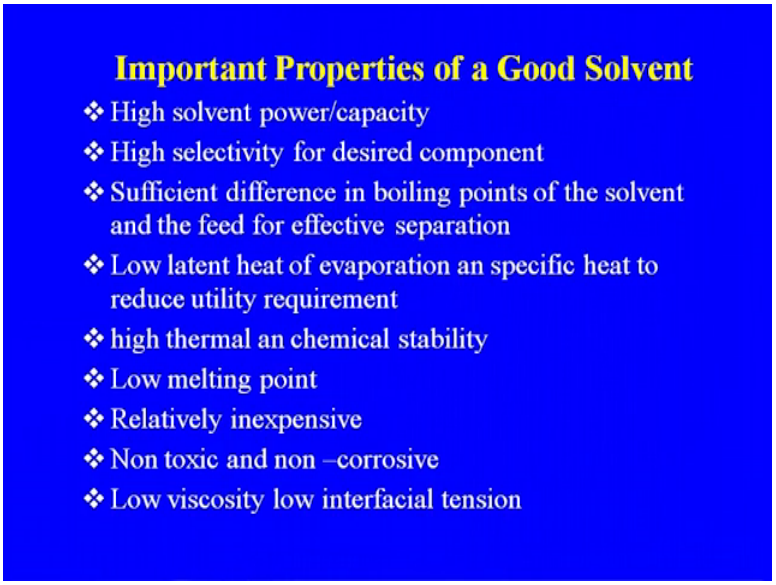

High solvent power capacity, high selectivity of the desired component because, the component which has to removed. Sufficient difference in the boiling points of the solvent and the feed for the effective separation, low latent heat of evaporation, high thermal and chemical stability because, the stability that is also very important. Even some of the cases, we are using the higher temperature, low melting point, relatively inexpensive, non toxic, non corrosive, this is the another requirement of the process low viscosity, low interfacial tension.

So, this was the actually the part of the introduction to the chemical process industry where, we discussed about the status of the chemical process industry, raw material of the chemical process industry and then, the various unit processes and unit operation that

is being used in chemical process industry. Now, in the next few modules, we will be discussing one by one the different chemical process industry and to start with the coal, chemicals will start with the coal and coal chemical.

Because, now the again, earlier we started the chemical industry with the from the coal to the same Fischer Tropsch process, again people are going for the coal for the, either it may be for the manufacture of synthesis gas for the fertilizer manufacture or from the synthesis gas to oil or synthesis gas to various petrochemicals. Now, we are talking about the coal to methanol technology, coal to plastic technology and the China that has taken the major step in utilization of their coal resources for the manufacture of the synthesis gas through the route.

But, from very beginning earlier because, you see the coal, use of the coal and coal chemicals first that actually, the we started using the coal chemicals from the coke oven plant. So, next in the next module on the module 2, we are having we will be discussing about the coal, coal coal chemicals, coke oven plants because, the coke oven plant that was the actually the starting, from where we are getting the aromatics. And some of the, even the ammonia and many of the steel plants, they are having the your fertilizer plant also ammonium sulphate, ammonium nitrate.

And 3rd module will be the on the gasification of the coal, gasification of the petrocoke, gasification of the biomass, that we will be discussing that we will be discussing in the lecture 3 of the module. Module 2 where, we will be detail about the gasification, what are the development that has taken place in the gasification and why we are going for the petrocoke or the biomass gasification.