Inorganic Chemical Technology
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Lecture - 01
Introduction and Unit Processes

Welcome to the MOOCs course Inorganic Chemical Technology. The title of today's lecture is Introduction and Unit Processes. In the introduction what we are going to see today? We are going to see a few statistics of Indian chemical industry and then we will be seeing the picture of raw materials; that means, availability of raw materials and then picture of energy etcetera in India for Indian chemical industry.

Because for any chemical production these two things are very essential raw materials and then energy requirements has to be fulfilled without any hurdles. So, that is the reason in addition to the statistics we are also going to see a few basics or the availability of raw materials and an energy sources etcetera for chemical industries that is what we are going to see then we will see a few basics of unit processes followed by unit operations.

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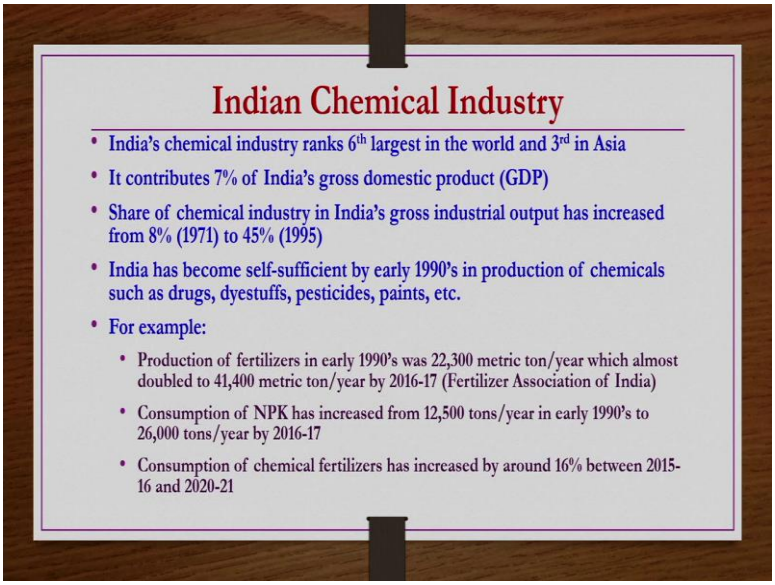

Indian chemical industry. Indian chemical industry is very huge it stands 6th worldwide and third in Asia such a huge industry is Indian chemical industry. It contributes 7

percent of India's gross domestic product that is GDP, 7 percent is a huge value 7 percent contribution to India's GDP is really a kind of huge value.

So, that gives a picture of how important is Indian chemical industry for the growth of our country India. Share of chemical industry in India's gross industrial output has increased from 8 percent in 1971 to 45 percent in 1995 and then it may be even more if you take current years statistics.

India has become self sufficient by early 1990s in production of chemicals such as drugs, dyestuffs, pesticides, paints etcetera why because for example, if you see production of fertilizers in early 1990s was almost 22,300 metric ton per year which has almost doubled to 41,400 metric ton per year by 2016 and 17 according to Fertilizer Association of India then consumption of NPK that is Nitrogen Phosphorus and Potassium these are the components usually present in almost all fertilizers.

The consumption of NPK has increased from 12,500 tons per year in early 1990s to 26,000 tons per year by 2016 and 17 so, that shows how much important how much progress are we making in fertilizer industry. Then consumption of chemical fertilizers has increased by around 16 percent between 2015-16 and 2020-21.

Then coming to the raw materials picture for India we are a country where natural resources are very huge so; obviously, it is expected that our resources raw material resources are huge.

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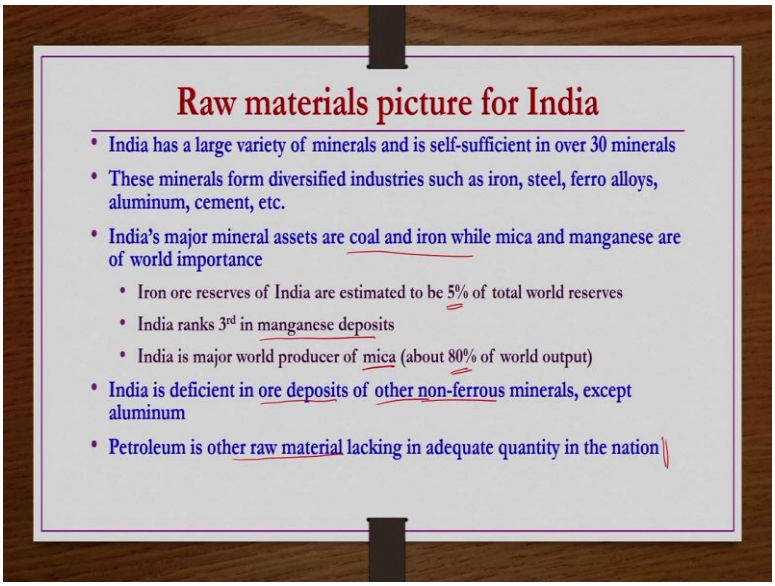

India has a large variety of minerals and it is self sufficient in over 30 minerals these 30 minerals again are used to for production of several types of chemicals. So, it is a huge number these minerals form diversified industries such as iron, steel, ferro alloys, aluminum, cement etcetera. India's major mineral assets are coal and iron while mica and manganese are of all importance.

If we see a particularly at few ores then Iron ore reserves of India are estimated to be 5 percent of total world reserves, it ranks third in manganese deposits it is major world producer of mica how much major what is the percentage if you see. 80 percent of the world output is coming from India in production of mica ok; however, India is deficient in ore deposits of other non-ferrous minerals except aluminum also petroleum is other raw material lacking in adequate quantity in the nation right.

So, that is the reason you know we are not completely self sufficient in terms of the oil, but in terms of other many chemicals such as drugs etcetera pharmaceuticals etcetera steel industry iron industry etcetera we are almost all self sufficient. But when it comes to the oil we are not self sufficient because our raw materials resources for raw materials to produce petroleum or oil products are fewer we are depending on majorly on exports.

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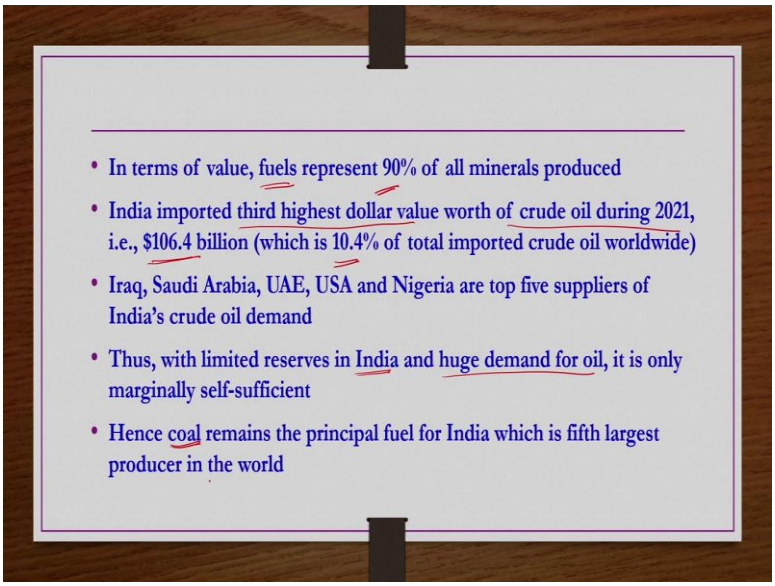

In terms of value fuels represent 80 percent of minerals produce. So, the such is high value of these fuels. And then in terms of imported value India imported third highest dollar value worth of crude oil during 2021 and then that is approximately 106.4 billion dollars which is almost like 10.4 percent of total imported crude oil worldwide.

Whatever the countries which are not having resources petroleum resources or crude oil resources in their own countries they obviously, depend on the importing and then many countries does importing of such crude, but we are import we are third highest importer we import almost 10.4 percent of total imported crude oil worldwide.

What are the countries that are supplying us these crude oils? Primarily Iraq, Saudi Arabia, UAE, USA and Nigeria are the top five suppliers of India's crude oil demand of course, we also import from other nations also, but these are the five important or top five suppliers of India's crude oil demand right.

Thus, because of the limited reserves in India and then huge demand for oil it is only marginally self-sufficient it is not completely self-sufficient when it comes to the oil because of this reason in India still coal remains the principal fuel for India which is fifth largest producer in the world right.

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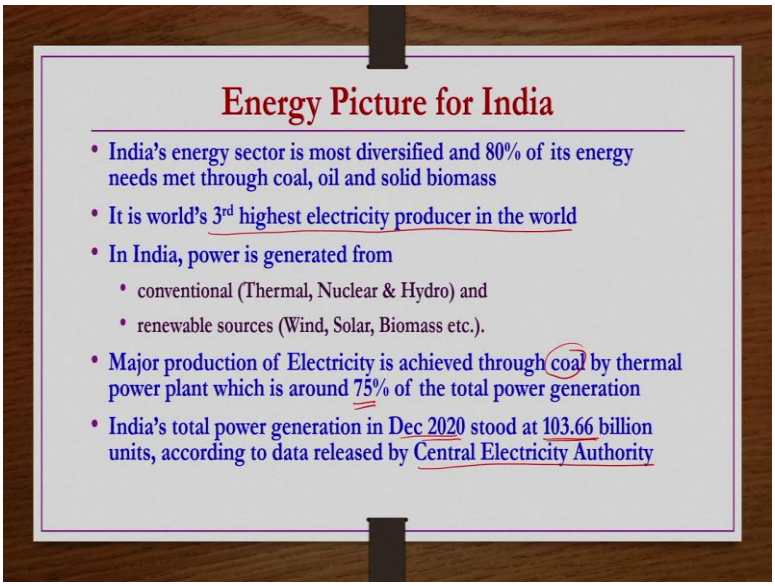

So, now we see what is energy picture for India. India's energy sector is most diversified and 80 percent of its energy needs made through coal oil and solid biomass. It is third highest electricity producer in the world. In India power is generated from both fossil and non-fossil fuels or fossil and non-fossil resources by conventional and non-conventional methods.

By conventional methods like thermal nuclear and hydro power plants we get majority of the power and then through renewable resources also like wind, solar and biomass etcetera also we are generating power. Major production of electricity is achieved through coal by thermal power plant which is around 75 percent of the total power generation India. 75 percent of the total power that is being generated India that is being generated by coal or combustion of the coal in thermal power plants ok.

India's most power generation in December 2020 stood at 103.6 billion units according to data released by Central Electricity Authority right. So, that much how many? 103.66 billion units of power has been generated in December 2020.

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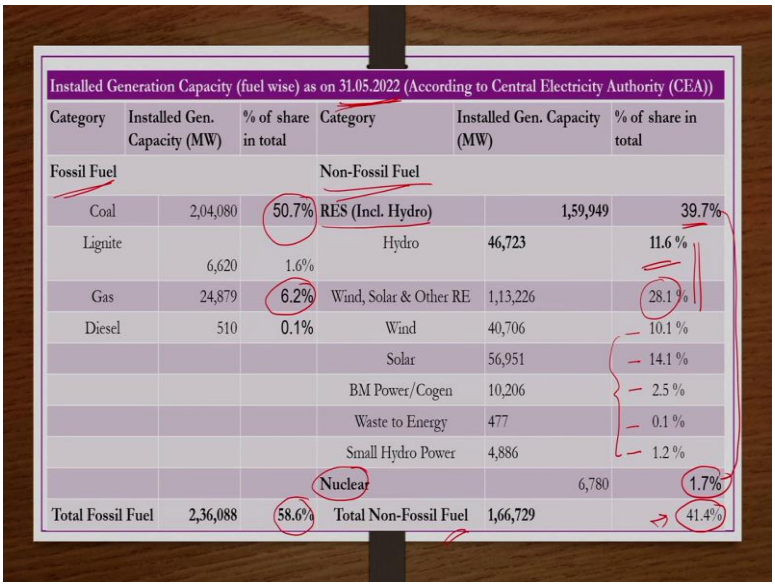

Installed Generation Capacity (fuel wise) as on 31.05.2022 (According to Central Electricity Authority (CEA))

Category	Installed Gen. Capacity (MW)	% of share in total	Category	Installed Gen. Capacity (MW)	% of share in total
Fossil Fuel			Non-Fossil Fuel		
Coal	2,04,080	50.7%	RES (Incl. Hydro)	1,59,949	39.7%
Lignite	6,620	1.6%	Hydro	46,723	11.6 %
Gas	24,879	6.2%	Wind, Solar & Other RE	1,13,226	28.1 %
Diesel	510	0.1%	Wind	40,706	10.1 %
			Solar	56,951	14.1 %
			BM Power/Cogen	10,206	2.5 %
			Waste to Energy	477	0.1 %
			Small Hydro Power	4,886	1.2 %
			Nuclear	6,780	1.7%
Total Fossil Fuel	2,36,088	58.6%	Total Non-Fossil Fuel	1,66,729	41.4%

Now, if you see installed generation capacity fuel wise, fuel wise in the sense fossil fuel versus non fossil fuel versus as an 31.5.2022 according to central electricity authority what we can understand that, total fossil fuels contribution in installed generation capacity is 58.6 percent out of which 50.7 percent is coming from the coal; whereas, 6.2 percent is coming from the gases and then remaining are the lignite and diesel.

Coming to the non-fossil fuels which includes renewable energy resources including hydropower and then nuclear power it contributes approximately 41.4 percent. 39.7 percent is renewable energy sources including hydropower that is addition of these two numbers 11.6 percent by hydro and then 28.1 percent by wind solar and other renewable energy resources.

This other renewable energy resources if you do compound wise, then we have this wind energy 10.1 percent, solar 14.1 percent, BM power cogen 2.5 percent and then waste to energy 0.1 percent, small hydro power 1.2 percent when you add these together then you get this 28.1 percent.

So, this 28.1 percent and this 11.6 percent adding together to making to 39.7 percent and then nuclear installed generation capacity is 1.7 percent. So, these two when we add together then it is 41.4 percent. So, total fossil fuel contribution is 58.6 percent, total non-fossil fuel contribution is 41.4 percent out of the total installed generation capacity

that indicates not only fossil fuel non fossil fuels also their contribution is also increasing drastically because these numbers are the recent numbers by 31.5.2022.

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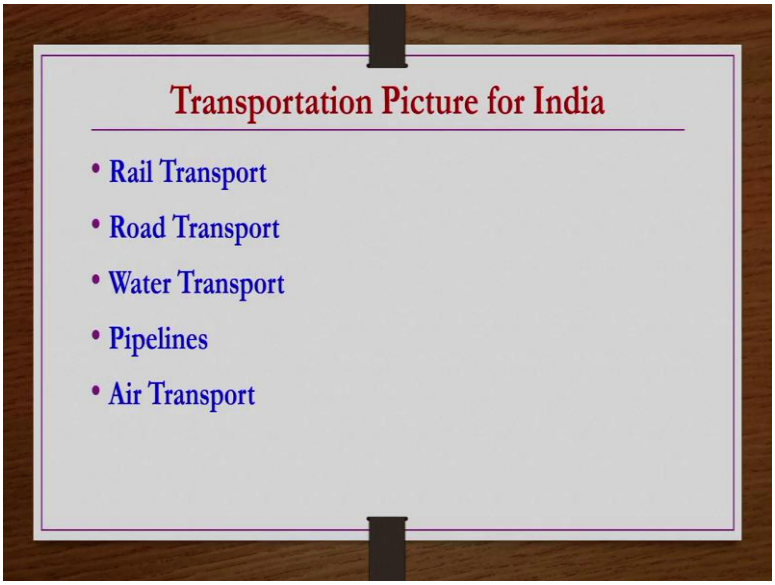

Now, transportation picture for India, transportation is also very essential for any chemical plant because sometimes you need to bring the raw materials from very different location compared to the from a location which is far away from the plant. And then also some many times in not many times almost always the product that you produce the chemicals that you produce in chemical plant that has to be dispersed to the various locations of the nation or sometimes if you are exporting out of the country also.

Then transportation is also very much essential from mechanics point economics of the plant point of view ok. If you do not have any proper transportation it may be possible that you are not making enough money out of your plant even though your plant is running very efficiently.

So, that is the reason transportation is also essential component as far as concerned to the chemical industries. So, what are the normal transportation sources that we have in India? Mostly by rail transport because nowadays these goods rails are being connected from one corner to the almost all corners of the India right.

So, then road transport is also better earlier couple of decades back it was not that good, but now road transport is also improved drastically, then water transport, pipelines also

one source of transportation because you know the oil from oil actually transported from the plant to the different locations of the country through pipes.

And then these pipes may be going several hundreds of kilometers and then pipes may be having diameter 50 centimeters, 1 meter or even higher value many a times you may be reading in news sometimes these pipelines are being broken and then gas or oil is being leaked.

So, that means, transportation of this crude or processed oil may be taking place through the pipelines. So, pipelines is also one of the mode of transportation for the chemicals then air transport is also sometimes used for transportation of some of the products. So, that is about a few statistics about Indian chemical industry and then raw material picture, energy picture and then transportation picture for India especially from chemical industry viewpoint.

So, now what we are going to see? We are going to see what is chemical industry what happens what it is and then what are the unit operations and unit processes we have few basics we are going to see now ok.

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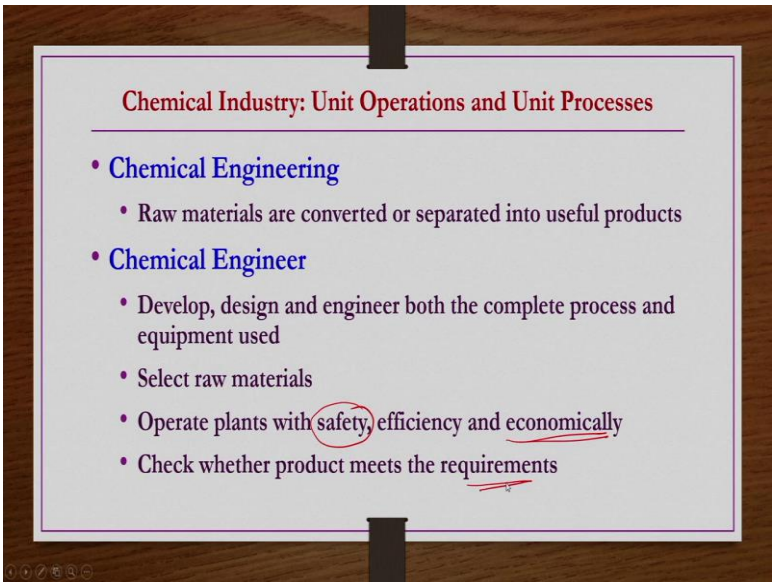

Chemical engineering in chemical engineering what we learn we learn how the raw materials are being converted or separated into useful products. It is not essential always to take place a reaction or more reactions to get a product from raw materials sometimes

like ore beneficiation etcetera are there wont't be any reaction there may be a purification of raw materials and then minerals taking place and then product mineral may be extracted or purified without any reaction.

So, it is not necessary that always after a reaction only you get a product without reaction also you get the products because depending on the nature of the industry that we are having. If you for you if the purified mineral is a product. So, then without any reaction you can get a purified minerals by ore beneficiation processes right.

But; however, in majority of the chemical plants what happens there are a chemical reactions one or more chemical reactions in order to get a product and then when you do this in addition to the product there may be byproducts and then because of not having any reaction 100 percent conversion there may be unreacted chemicals are also there ok.

So, separation of the products right useful separation of the useful products is also takes place are you know we learned in chemical engineering discipline right. So, what does chemical engineers they do? They do develop, design and engineer both the complete process and equipment used because process is having several equipment soon we are going to see in any flow sheet or any process description that we are going to discuss any of that you take you can see there are n number of equipment are being used right.

So, the those equipment design of those equipment is also essential. Then selection of raw materials selection of raw materials is also important sometimes only one source of raw material may be there sometimes more than one number of sources of raw materials may be there for a given product for a required product generation or production of any chemical then selection is also important both from the economics point of view as well as the safety point of view etcetera also.

And then as well as the time point of view also sometimes what happens? The raw materials may be available cheaply from a far away distance compared to the nearby distance, but you know the time lapse may not be useful that may cause a kind of loss to the plant. So, such kind of parameters may be there in selection of raw materials as well.

Then operate plants with safety efficiency and economically safety is very much essential for the people working in the plant as well as nearby area of the plant and then

economically. Economically also it is very essential to make sure that plant operates profit under profitable condition that also be to be taken care by the chemical engineers.

And then check whether the product meets the requirements of the consumer or not that is also need to be checked by the chemical engineers.

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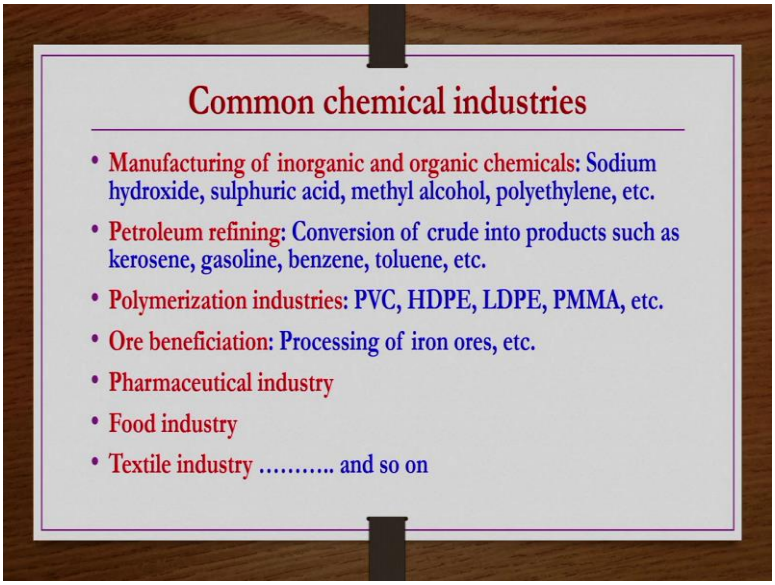

Then now we see a few common chemical industries, some of the chemical industries like manufacturing of inorganic and organic chemicals like sodium hydroxide, sulphuric acid, methyl alcohol, polyethylene, polyvinyl chloride etcetera. Then petroleum refining industry like conversion of crude into products such as kerosene, gasoline, benzene, toluene etcetera then polymerization industries like production of polyvinyl chloride high density polyethylene low density polyethylene poly methyl methacrylate etcetera these kind of polymers.

Then ore beneficiation where processing of iron ores etcetera taking place, then pharmaceutical industries, food industries, textile industries and so, on. So, there are a number of chemical industries are there. The purpose of listing these industries to have a kind of feel or realization that almost all industries the requirement of chemical engineers is there without chemical engineers involvement none of these industry may run efficiently ok.

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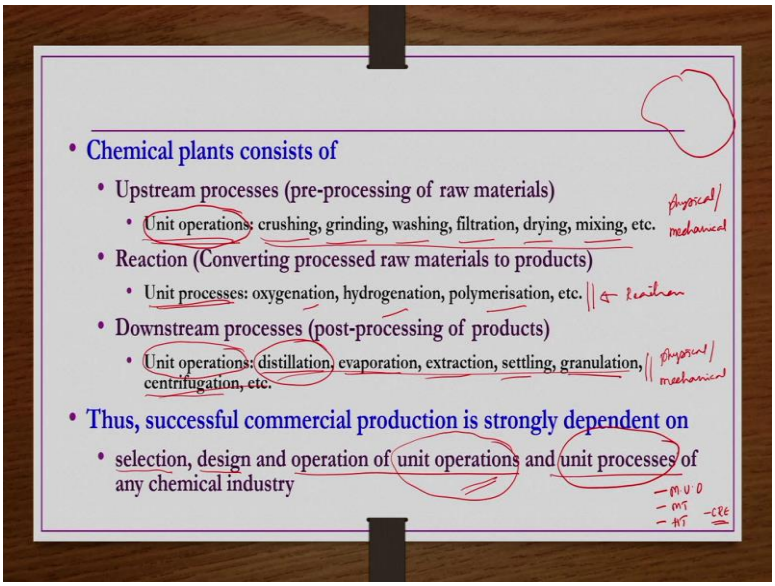

Now, we see about the chemical plants. Chemical plants what we understand there is a reaction occurring; obviously, so, that to get a product there may be byproducts there may be unreactant unreacted reactants etcetera that is a different issue. But raw materials that we get from the natural resources we may not directly using them as it is for a reaction in the reactor ok there may be some kind of preprocessing or purifying of raw material etcetera or size reduction of raw material etcetera are required right.

So that means, before the reaction there are few steps that are to be taken care and then all those thing to be taken care by the chemical engineers in chemical plant let us call them preprocessing units ok. And then reaction stage is the one stage right after the reaction again products are forming.

The products purification of the products has to be taken care right or you know separation of the unreacted you know reactants taking off the byproducts etcetera making the product more purified than the produce one etcetera may also required to be done after the reaction without any reaction right.

So, that is known as the purification of the product stage or we can call them post processing stage like that, the entire chemical plant we can make into three stages; one stage is upstream processes stage which is also known as the pre processing of raw material stage, then reaction stage where converting process to raw materials to products

taking place and then downstream processes where post processing of products takes place.

So, now, how this upstream process or pre-processing of raw materials take place? Let us say you are generating power by coal combustion now. Now, coal you get in big big lumps you know big big lumps like some coal rocks may be having diameter 5 to 10 meters or even bigger, some may be having 1 meter some may be having few centimeters like that different size particles may be there.

Now all of them may not be suitable directly to take to take them into the combustion reaction right fluidized bed combustion if you are doing in the fluidized bed you cannot take such big particles. So, then you have to reduce them in the size so, that it is suitable to process in the combustion or combustion combusting reaction wherever the combustion is taking place whichever reactor you are taking usually fluidized bed reactors are used for these coal combustions ok.

So, then accordingly you have to do size reduction then when you take out this coal from the natural sources these coal are also having some impurities like mud that etcetera all those things or maybe some other minerals may also be there naturally possible because this coal you excavating from the underneath of the earth you are taking them right.

So, then you have to separate them otherwise they may be interfering the reaction right. So, for that you what you have to do? You have to crush them into the smaller size suitable to feed into the reactor and then before after crushing directly you cannot put them into the reactor you have to wash them so, that to remove the dirt, mud etcetera those things should also be removed right.

So, washing may be required ok then after washing you know coal may become wet. So, you cannot take the wet coal into the reactor otherwise you may not get your reaction may not be efficient. So, again you have to dry the crushed coal crushed and washed coal. So, these kind of steps are required.

So, all these things are you know known as the preprocessing steps upstream processes we call them in general as a common terminology where we may have crushing, grinding, washing, filtration, drying, mixing etcetera. And then what you understand by

terminology of these processes or operations? You can see them there are only physical changes. When you crush is there any reaction taking place?

No. When you wash is there any reaction taking place? No. When you are drying is there any reaction taking place? No. You are dryings are such a temperature the reaction does not take place combustion does not take place right. Filtration when you are doing is there any reaction?

No. So, what I mean to mention that all these processes when they are taking place either physical or mechanical changes only occurring no chemical changes are occurring ok. So, these kind of operations where only physical or mechanical changes occurring we call them unit operations. We call them unit operations from chemical engineering terminology point of view right.

Now, given a natural resource you have crushed it, size reduced it, purified it, dried it, everything washed and dried washing drying everything you have done then now you have a processed raw material processed raw material you are having after upstream after completing the upstream processes right.

Then this processed raw material you have to fit the reactor let us say fluidized bed reactor where coal combustion is taking place. Coal we I am taking an example. So, that to explain easily any chemical plant these are the things are common ok. So, in the fluidized bed combustion reactor combustion is taking place right then products are forming.

So, in the reactor different types of reactions may take place here I am taking combustion in general. So, otherwise depending on the chemical that you are producing there may be oxygenation reaction, there may be hydrogenation, polymerisation reaction, dehydration reaction may be there.

Deoxygenation reaction may be there, hydro deoxygenation reaction may be there, nitration sulfation, different kind of reaction nitration, sulfonation, different kinds of reactions are possible. So, these reactions the equipment in which these reactions are taking place are also essential from the chemical point of view and these reactions in general we call them unit processes we call them unit processes and then these unit processes are n number of are there.

All of them we cannot cover we are going to see about 25 to 30 unit processes which are common or commonly it is required to understand for a UG chemical engineering student right. Then let us say reaction has occurred now product has formed you have to purify the product either by separating the byproducts or taking out the or recycling the unreacted reactants etcetera all those things you have to do even if those things are not there you may be needing to purify them increase their percentage.

Let us say in process you are producing a ethanol and water mixture has come as a product now you wanted to increase the ethanol percentage in the product ethanol is only there 70 percent you wanted to make the product purity as 95 percent pure. Then you have to do certain other processes we call them downstream processes or post processing of the products where we may do something like distillation alright.

It depends on the process to process evaporation may be there, extraction may be there, settling granulation centrifugation and so, on so different types of operations are there. And then these operations are also there are only physical there are only physical and are mechanical changes only there is no reaction involved.

There may be temperature gradient involved in order to the process to take place, but there is no reaction ok. There may be pressure involved in order to take in order to purify the product or whatever is the post processing is required, but there is no reaction a reaction is there only in the unit processes.

So, these operations such as distillation, evaporation etcetera they are also physical or mechanical processes only there are no chemical changes. So, these are also known as the unit operations. Now what you understand? Chemical plant is a combination of several unit operations and unit processes that you can understand. But what you understand? There may be fewer reactions are there right.

So, there may be one or two reactors required in order to; in order to make sure the required reaction taking place, but before that reaction and after that reaction you can see so, many unit operations are there so, many unit operations are there what I mean to say that the number of unit operations are more in any given plant compared to the unit processes and thus their design construction is going to make huge impact on the overall performance of the chemical plant fine ok.

So, the successful commercial production is strongly dependent on selection design and operation of unit operations and then unit processes of any chemical industries right. More than 60 to 70 percent of capital investment is on unit operations basically and then connections pipe connections etcetera ok in any of the chemical plant if you take.

So, not only unit processes unit operations selection design and operation of a unit operations is also very essential from the operating of the chemical plant viewpoint successfully. Successfully in the sense operating them safely, efficiently and economically all three are important ok.

So, now in this week we are going to see a few more details about the unit operations and unit processes in coming slides as well as the coming lectures couple of lectures, but before going to the next slide what I would like to mention that, let us say distillation itself is a huge topic and then when you do the mass transfer courses etcetera you can see that huge topic is converted into one or two chapters or something like that.

Likewise, individual unit operations if you see they are wider topic we cannot go into details of each and every aspect of the these unit operations or unit processes their size operation working principles deriving equations and all that we are not going to see. We are going to see only basics what is going to happen in a given unit operation what is a given unit process that is what we are going to see basics.

Because detailed unit operations you may have other courses like mechanical unit operations one course is there in there you see the details of a mechanical unit operations, then in mass transfer you see several types of unit operations being discussed, then heat transfer course also several types of unit operations being discussed then a chemical reaction engineering kind of courses you see variety of a unit processes.

So, individual courses are there to discuss about the in detail about unit operations and unit processes thus, we are going to see only a few basics what are the kind of thing what for what for they used only that much only we are going to see in this particular course ok because this course is on production of inorganic chemical technology this course is not on unit operations or unit processes ok.

However, this is the fourth or fifth semester course in majority of the universities. So, then it is very much essential to know what are these unit operations and unit processes right now in this course itself ok.

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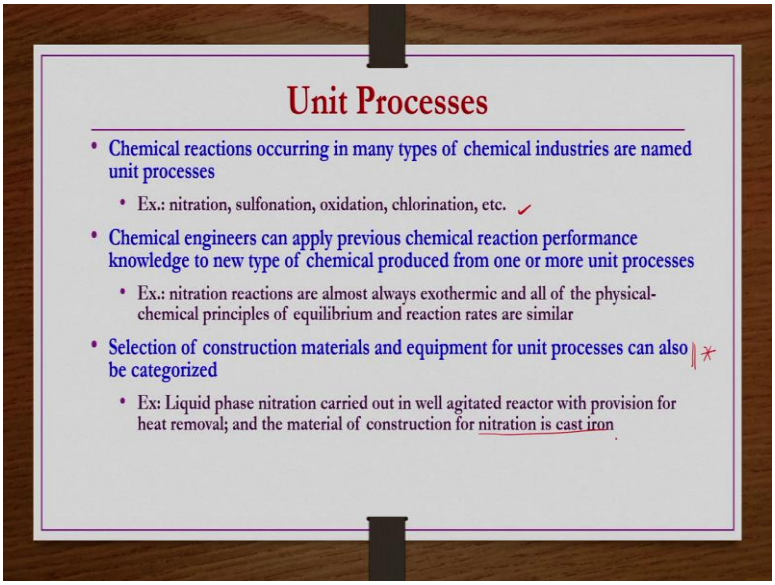

Now, we see a few basics about unit processes. Chemical reactions occurring in many types of chemical industries are named as unit processes example nitration reaction, sulfonation reaction, oxidation reaction, chlorination reaction I have given reaction associated with the inorganic chemicals production only there may be other reactions associated with inorganic chemical production.

Of course, we are going to see them as well in detail in the next slide onwards then chemical engineers can apply previous chemical reaction performance knowledge to new type of chemical produced from one or more unit processes. Let us say nitration is there right.

So, the nitration reactions are almost exothermic always and their physical chemical principles of equilibrium and then reaction rates are similar in general. So, whatever the principles of equilibrium and reaction rate information etcetera are there for these nitration reactions they may be taken into consideration for designing or you know development of other products wherever these nitration kind of reactions are also included ok.

So, that is example nitration reactions are almost exothermic and thus all of the physical and chemical principles of equilibrium and reaction rates of such nitration reactions are similar. So, then that information can be used wherever it is required by the chemical engineers, they need not to do those processes those development of equilibrium and then reaction rates etcetera are not necessary each and every time.

And then selection of construction materials and equipment for unit processes can also be categorized. It is also very important because some reaction you may be doing in batch reactors, some reactions you may be doing in batch reactors, some reactions you may be doing in continuous reactors or you know combination of batch and continuous reactors those kind of things you are going to see the different types of batch and continuous reactors in chemical reaction engineering course anyway.

So, depending on the nature of the reaction the construction material for the equipment where this reaction is taking place is also very essentials because some reactions may be taking place at ambient conditions just by mixing some reactions may be taking place at slightly higher temperature and slightly higher pressure, but some reaction may be taking place only at very high temperatures and high pressures. So, the material of construction of the equipment cannot be same under all conditions right.

So, if a reaction is taking place at lower temperature, atmospheric temperature and pressure then why do you waste the money in using a construction material for the reactor which is sustainable for high temperature and pressure because the material that is sustainable at high temperature and pressure; obviously, that will be going to be expensive.

So, that is the reason you know you have to be careful while selection of the material of construction for the; for a given unit process right. So, for example, liquid phase nitration carried out in well agitated reactor, it is a batch kind of reactor with a provision for heat removal and then material of construction for nitration is cast iron is sufficient right.

But the reaction is occurring at high temperature and pressure then that material of construction for that or such kind of reaction if you are using cast iron that may not be good enough ok.

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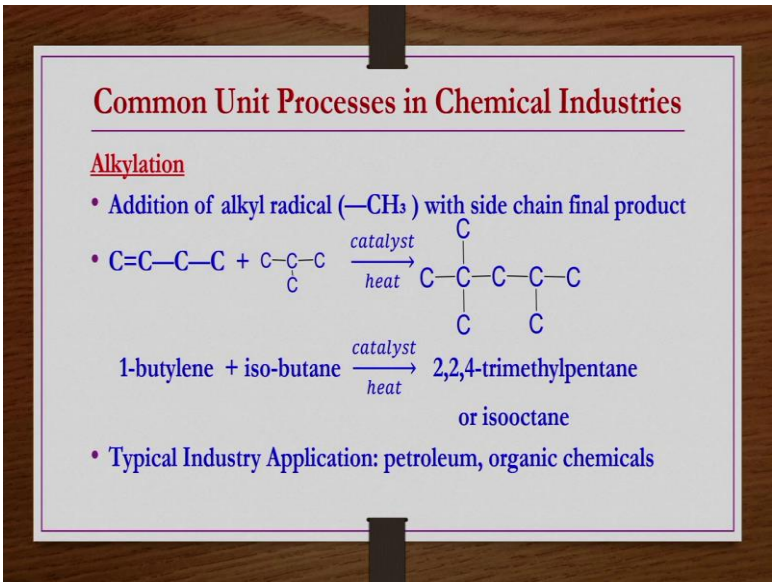

Now, quickly we see common unit processes in chemical industries. Let us start with alkylation, alkylation is addition of alkyl radicals that is CH 3 with side chain final product. So, that let us say if you have one butylene and then if you do alkylation reaction with iso butane then you can get iso octane like this in the presence of heat and catalyst ok.

These are the representative reactions kind of thing we are not giving exact temperature pressure or exact type of catalyst as I mentioned we are going to see a few basics these are the very common unit processes that are occurring in chemical industries there may be n number of unit processes or reactions occurring are available in the chemical engineering discipline.

But we are not going to see all of them we are going to discuss a few of them as a kind of a basic knowledge where we have such kind of alkylation reactions in general in petroleum and petroleum and other types of organic chemicals production plants you see such kind of alkylation reaction.

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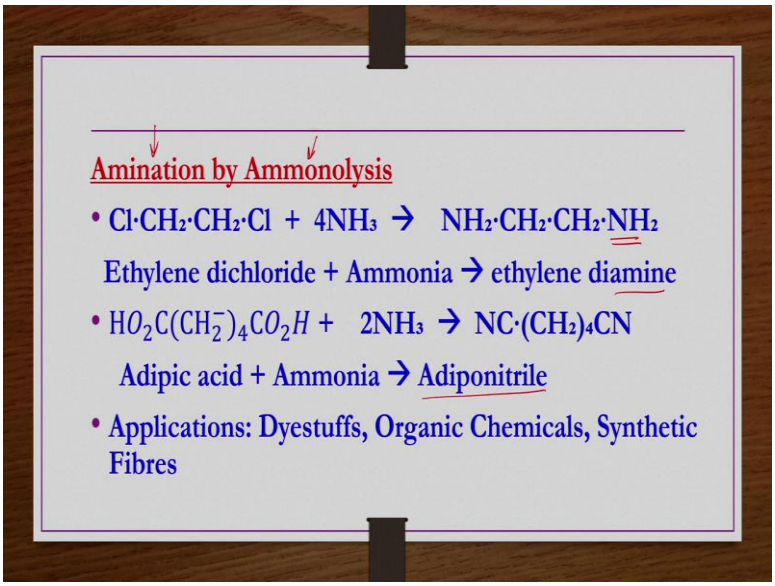

Then amination by ammonolysis right. Amination is nothing, but you are adding amine group NH 2 group to a organic component right. So, that reaction is taking place how it is taking place? By adding ammonia, it can be done different ways also those things are also we are going to see. Let us say you have ethylene dichloride and then if you react it with ammonia then you can get ethylene diamine this NH 2 if you get it is becoming amine.

Similarly, adipic acid if you react with ammonia then you get adiponitrile where do we get such kind where do we find such kind of chemicals? In applications in dye stuffs, many organic chemical synthesis and then synthetic fibers we usually use adiponitriles.

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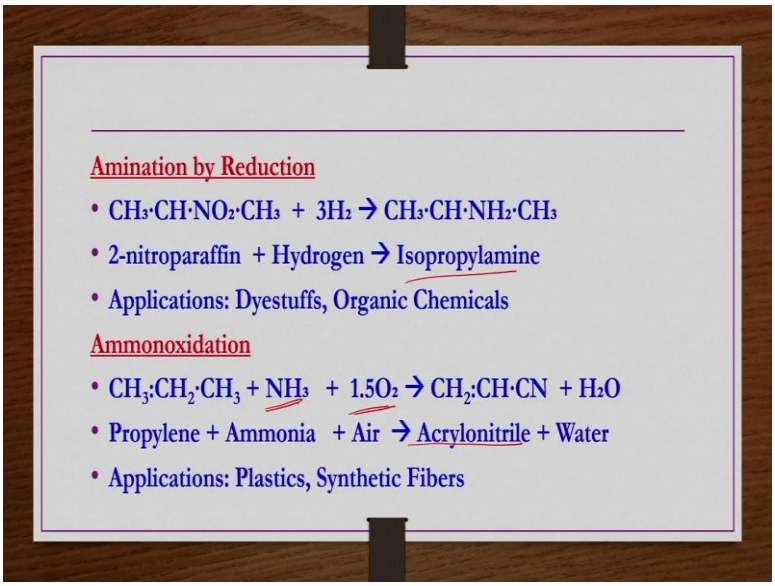

Then amination by reduction. Again the amination reaction only, but by reduction through how? If you do some kind of reductions then you can produce amines how? One example you have let us say two nitro paraffin if you are having you react with the hydrogen then you get iso propylamine.

Applications dyestuffs, organic chemicals, then ammonoxidation here what you have? Organic component is being reacted with ammonia and then oxygen that is the reason these reactions are known as the ammonoxidation ok; where let us say example propylene if you react with ammonia and air, then you will get acrylonitrile as a product. This acrylonitrile is often used in plastics and fiber synthetic fibers industries.

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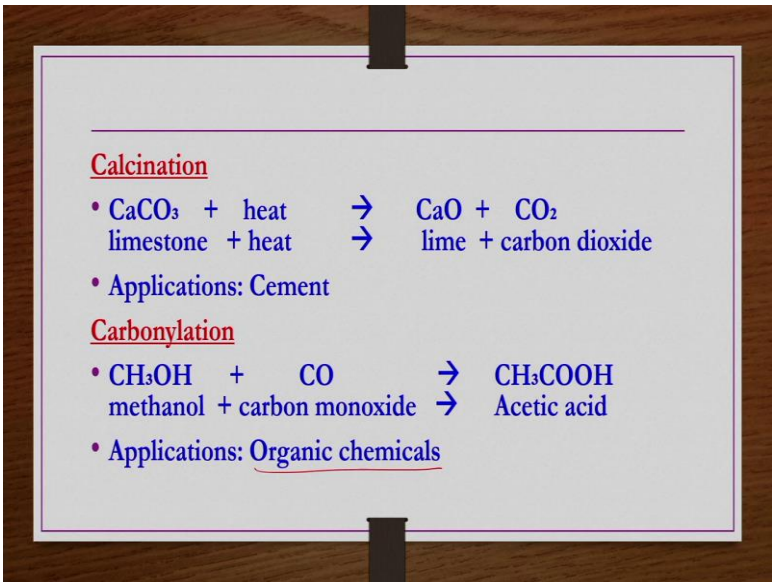

Then calcination very well known reaction for almost all chemical engineering students, where limestone if you heat you get lime and carbon dioxide. Applications is cement industry then carbonylation here we react with the carbon monoxide so, that is the reason this reaction is called as carbonylation let us say methanol plus carbon monoxide if you react then you get acetic acid acetic acid is very much used in many of the organic chemical synthesis and in process applications.

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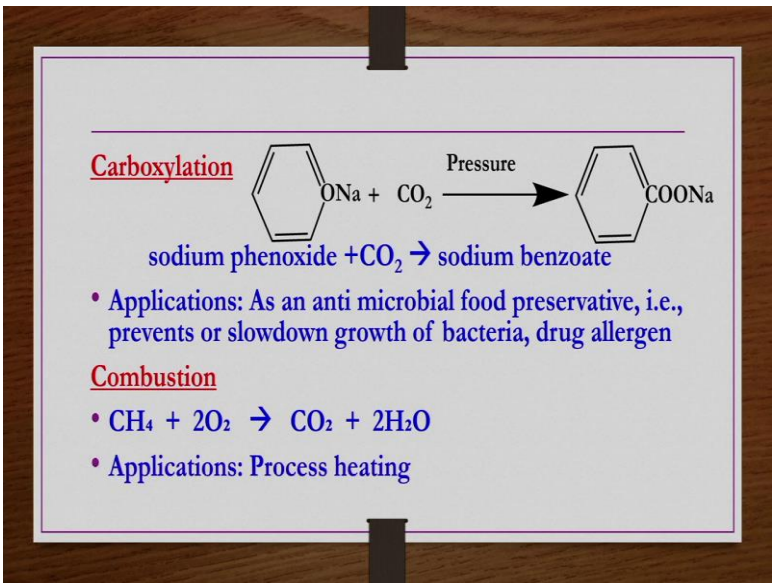

Then carboxylation. So, here what we do? We react with carbon dioxide to get certain products. So, for example, if you have sodium phenoxide and then react with the carbon dioxide, then you get sodium benzoate right. This sodium benzoate is often used as a antimicrobial food preservative it prevents or slow down the growth of bacteria drug allergen kind of thing are the applications of this sodium benzoate, then combustion.

Combustion is a common terminology for the reactions like let us say combustion; that means, you know you are reacting a component in the presence of oxygen right applying some energy heat then to get some products that is a common way right. There are there may be n number of combustion reactions may be there.

For example, methane combustion if you do using oxygen then you get carbon dioxide and water and then this reaction is very much common in process heating, applications in process heating applications.

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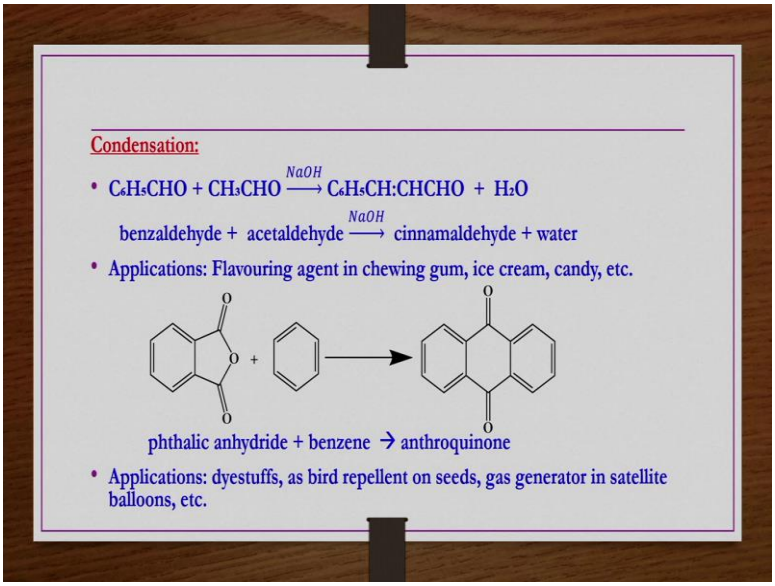

Then condensation let us say if you have benzaldehyde and then acetaldehyde, if you react them together in the presence of sodium hydroxide then you get cinnamaldehyde and water application this cinnamaldehyde used as a flavouring agent in chewing gum, ice cream, candies etcetera.

Then phthalic anhydride and benzene if you react together you get anthroquinone applications are dyestuffs which is also used as a bird repellent on seeds, gas generator in satellite, balloons etcetera.

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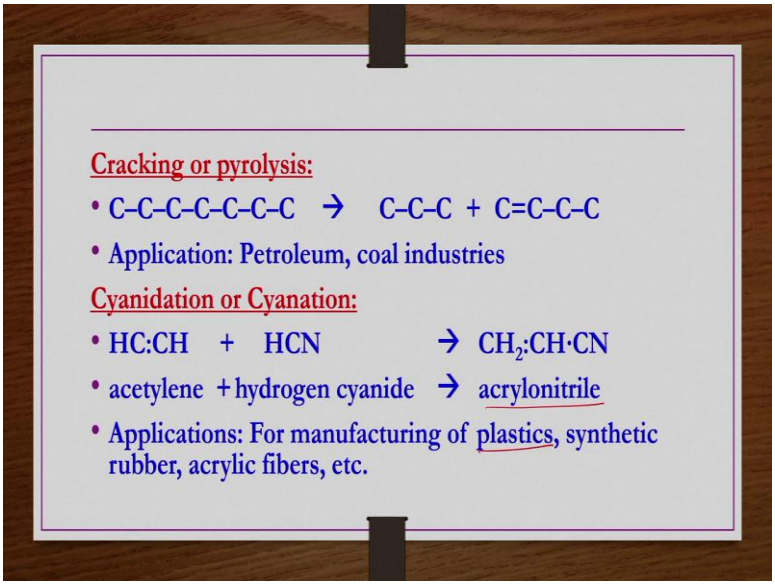

Then cracking our pyrolysis. Cracking our pyrolysis is nothing, but in the presence of or in inert atmosphere you apply the energy to a bigger size molecule. So, that to get smaller size molecules organic molecules etcetera that is what happens in the pyrolysis or cracking. For example, representative reaction a molecule with a 7 carbon atoms are there if you do the pyrolysis then it is possible that you can get a 2 components like this right.

Such kind of pyrolysis or cracking reactions are very common in petroleum, coal industries and then biomass, bio energy etcetera. Cyanidation or cyanation reaction. Let us say acetylene if you react with hydrogen cyanide then you can then you can get acrylonitrile it is acrylonitrile is very much used in plastics industries, synthetic rubber, acrylic fibers etcetera.

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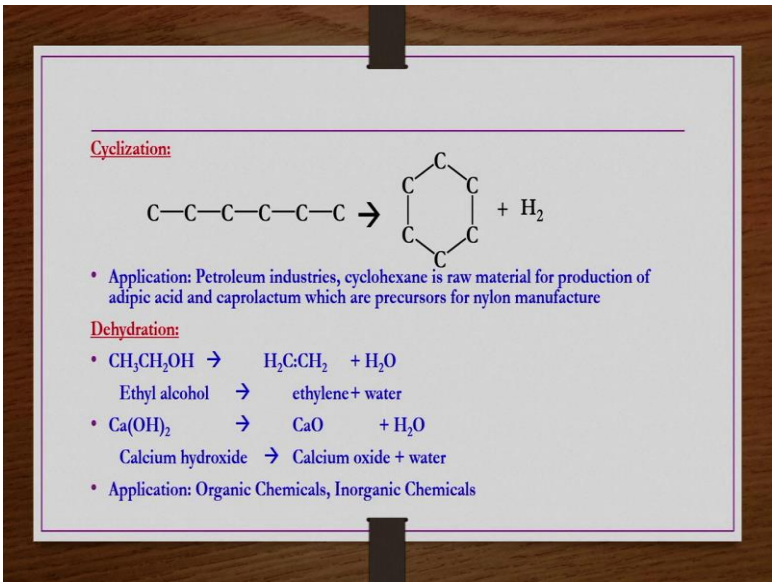

Cyclization reaction in general linear molecules organic molecules or whatever are there if you remove hydrogen by some provisions, then there is a possibility of cycling cyclic molecules formation possibilities are there. So, let us say this component if you remove hydrogen by some means then it is possible that you can get cyclohexane from n-hexane you are getting cyclohexane.

This cyclohexane is very common in petroleum industries it is also a raw material for production of adipic acid, caprolactum which are precursors for nylon manufacture etcetera. Then dehydration reaction dehydration hydration means that dehydration means removing the water molecules, let us say ethyl alcohol if you do the dehydration then you can get ethylene and water.

Similarly, calcium hydroxide if you do the dehydration then you can get calcium oxide and water. Applications are possible in many organic chemicals and inorganic chemicals productions.

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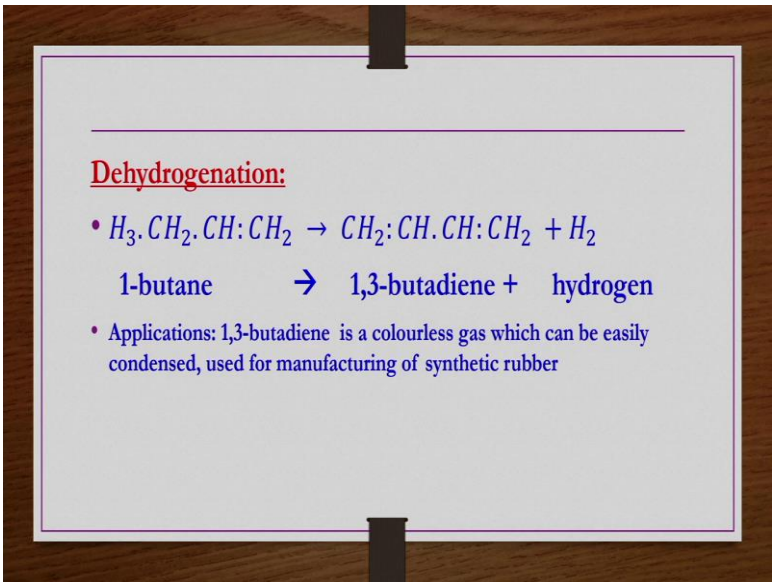

Then, dehydrogenation that is removing the hydrogen. So, that is the reason it is a dehydrogenation reaction for example, you have one butane if you do the dehydrogenation by removing the hydrogen, you can get 1, 3 butadiene and then hydrogen as products and this 1, 3 butadiene is a colourless gas which can be easily condensed used for manufacturing of synthetic rubbers.

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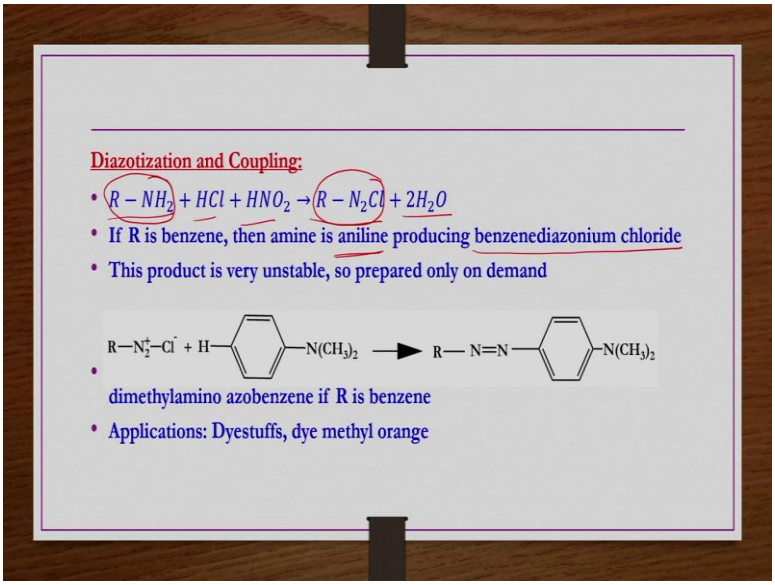

Then diazotization and coupling reactions let us say you have an amine and then reacting with HCl in HNO 2, then you can get R N 2 Cl and then water molecule right. So, this

amine is nothing, but let us say aniline these amine we can call it an aniline if this R is benzene right if it is C 6, H 5 NH 2 then that is called as aniline it is producing benzenediazonium chloride this is nothing, but benzene diazonium chloride and then it is very unstable products.

So, that is the reason it is prepared on demand and then supplied it cannot be stored for long time. Then another type of reaction here we have dimethyl amino azobenzene are produced if R is benzene here right, applications are there dyestuffs dimethyl orange etcetera.

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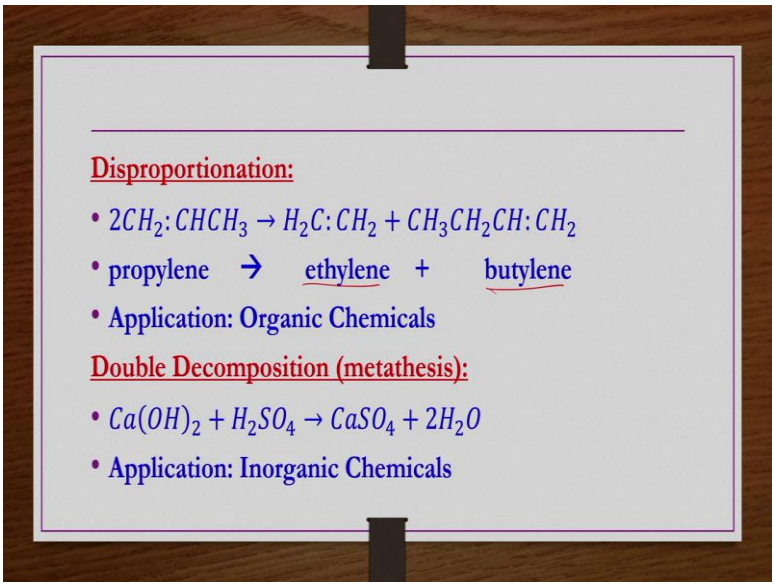

And then disproportionation reactions alright. Let us say two molecules of propylene if you react then it is possible that you can get ethylene and then butylene ok. Applications are organic chemicals and double decomposition are metathesis reactions let us say calcium hydroxide if you react with sulfuric acid, then calcium sulfate you get inorganic chemicals industries often we see such kind of reactions.

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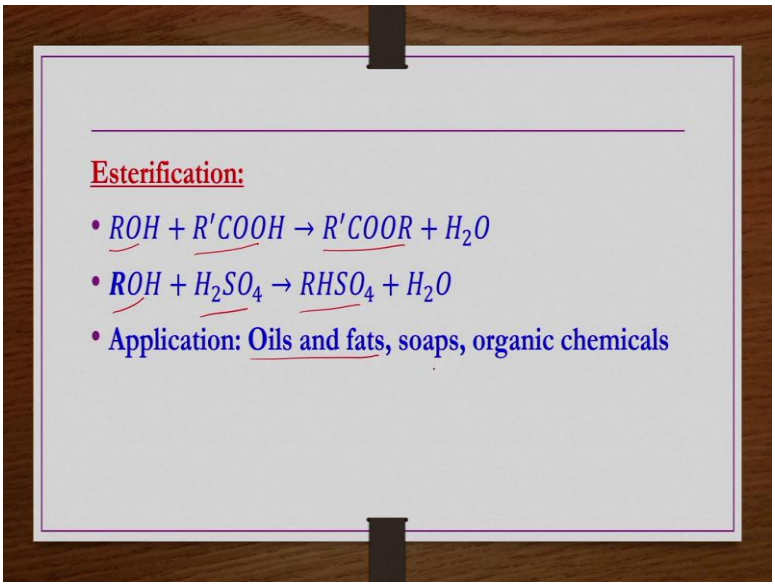

Then esterification reaction let us say you have alcohol and then carboxylic acid if you react together, then you can get ester. Similarly, alcohol if you react with the sulfuric acid then also you can get the sulfate product like this. So, these esters etcetera are often used in oils and fats soaps and detergents industries etcetera.

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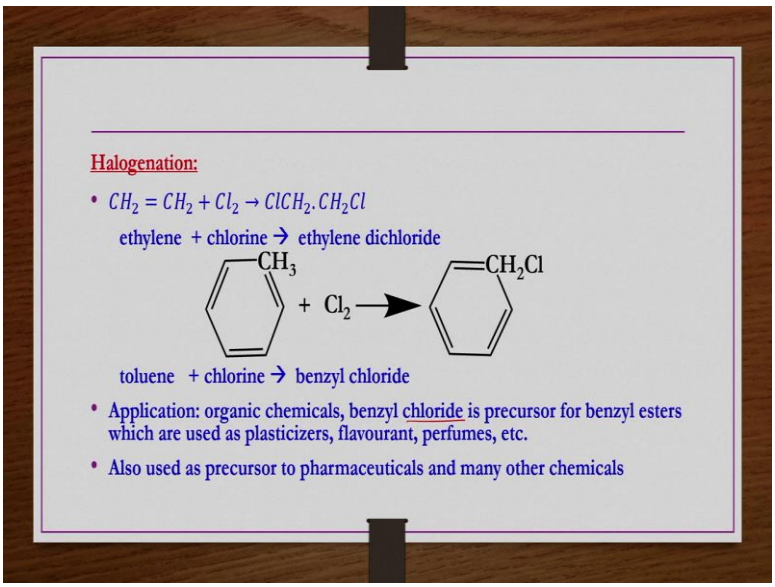

Reacting and halogen with organic component is halogenation kind of reaction ok. So, for example, you have ethylene and then chlorine reacting together you get ethyl ethylene dichloride. Similarly, you have toluene and then you react with the chlorine you

get benzyl chloride. Applications are you know many inorganic chemicals benzyl chloride is a precursor for benzoyl esters which are used as plasticizer, flavourant perfumes etcetera.

It is also used as a precursor for many pharmaceuticals and many other chemicals.

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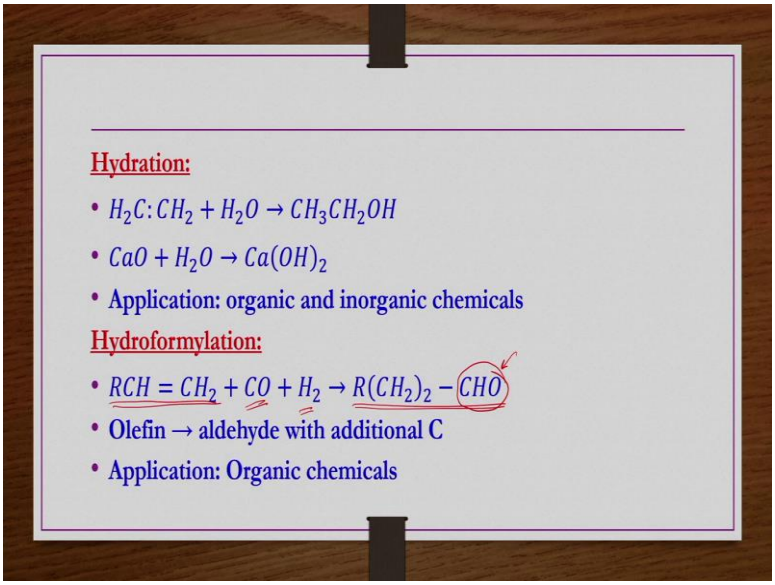

Then hydration: dehydration means removing the water molecules hydration in the sense adding the water molecules right. Let us say you have ethylene adding water and then reacting them you try to get ethyl alcohol we are not specifying the reaction temperature pressure catalyst etcetera that is not required. Similarly, calcium oxide if you react with water then you can get calcium hydroxide applications are available in organic and inorganic chemicals production.

And then hydroformylation reaction let us say olefin being reacted to get aldehyde let us like in this fashion by addition of C let us say R CH 2 CH 2 CO and then H 2 are being added so, that this aldehyde component CHO functional group if you are having then we are that means, that is a that component is a aldehyde components and then aldehydes are often common in many of the organic chemicals.

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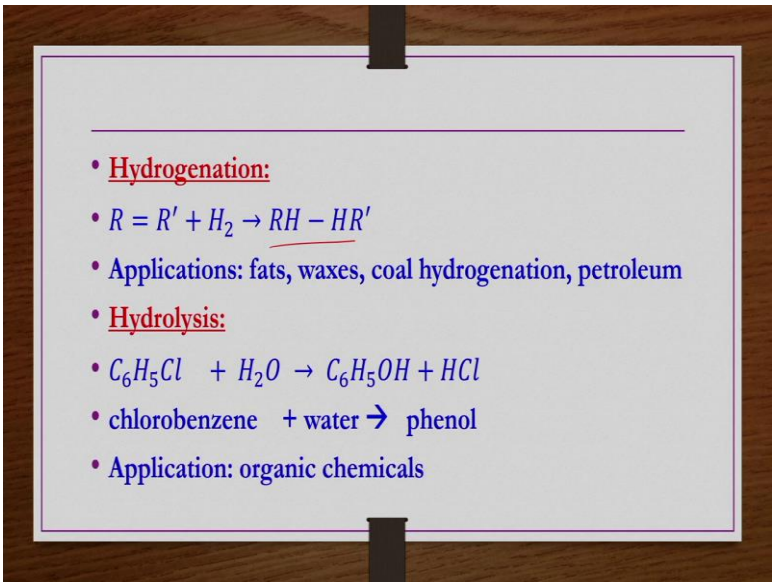

Hydrogenation; that means, adding of the hydrogen. Dehydrogenation is removing the hydrogen hydrogenation is adding the hydrogen to a component let us say R double bond double prime R if you are reacting with H 2 then you can get RH HR prime applications like fats, waxes, coal, hydrogenation, petroleum etcetera similarly hydrolysis is one type of reaction where example is you know chlorobenzene is reacting with water to get the phenol.

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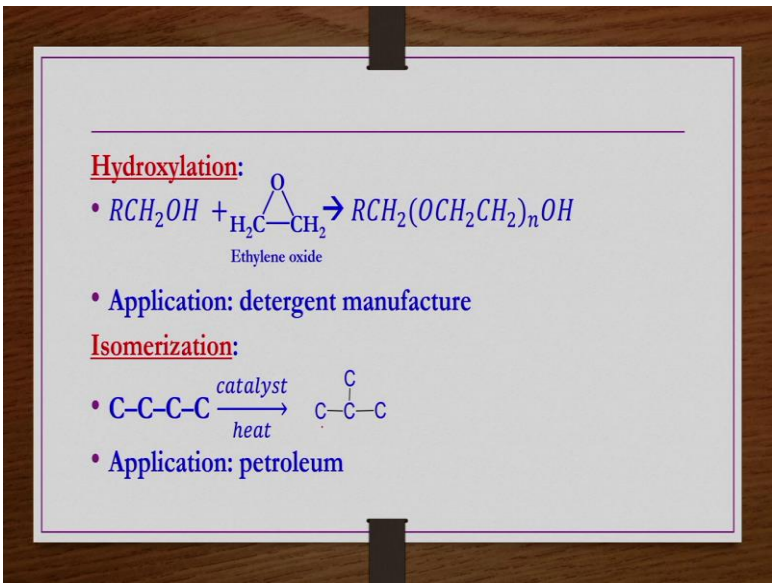

Then hydroxylation is another type of reaction where let us say one alcohol is reacting with the ethylene oxide, then you are producing a bigger alcoholic component like this. So, these are you can find in detergent manufacturing industries as application then isomerization reactions.

Let us say you have a linear four component n butane is there. So, then you apply heat in presence of catalyst then you can get iso propane you may get application in petroleum industries.

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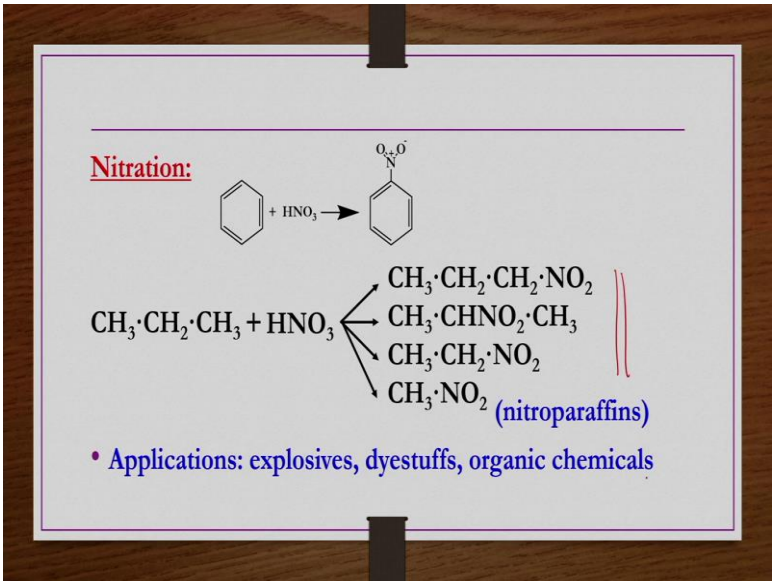

Similarly, nitration reaction let us say you have a benzene ring react with the nitric acid then you get nitrobenzene ok. Similarly, you have a other linear similarly you have other linear organic let us say here we are having n propane reacting with the nitric acid then we get nitroparaffins like this different are possible depending on the conditions etcetera applications are explosives dyestuffs organic chemicals.

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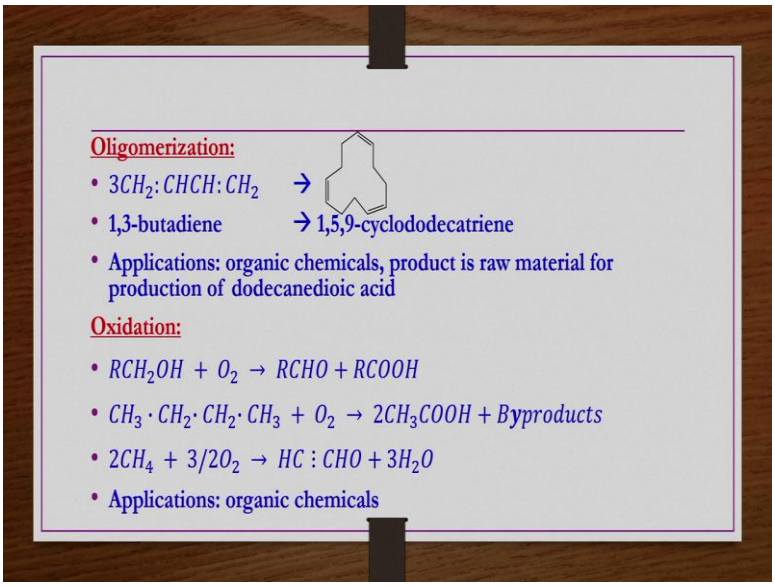

Then oligomerization let us say you have 1, 3 butadiene if you do oligomerization you can get a component like the 1, 3, 5 cyclododecatriene. Applications are there in many organic chemical industries, then oxidation let us say one alcohol if you do the oxidation then you can get a aldehyde and then carboxylic acid like here I have shown some more are shown here.

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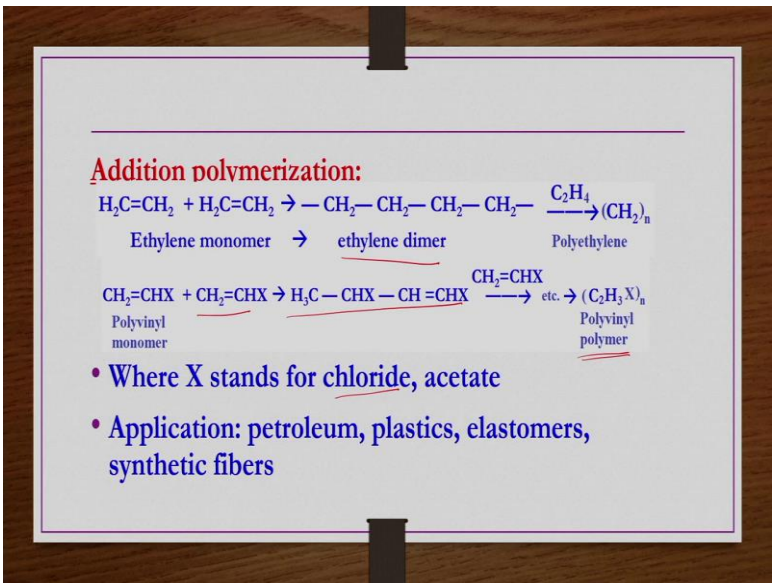

Addition polymerization let us say ethylene monomer you are having you add them together then ethylene dimer you may get like that if you keep on adding then you can

get polyethylene. Similarly, polyvinyl monomer you are having CH 2 double bond CHX if you keep adding like this then you can get you know dimers like this and then keep adding like this then it is possible that you get polyvinyl polymer ok.

So, here X is for the chlorides or acetate if it is Cl then it is polyvinyl chloride, if it is acetate then polyvinyl acetate. Petroleum plastics elastomers synthetic fibers are some kind of applications where we use them.

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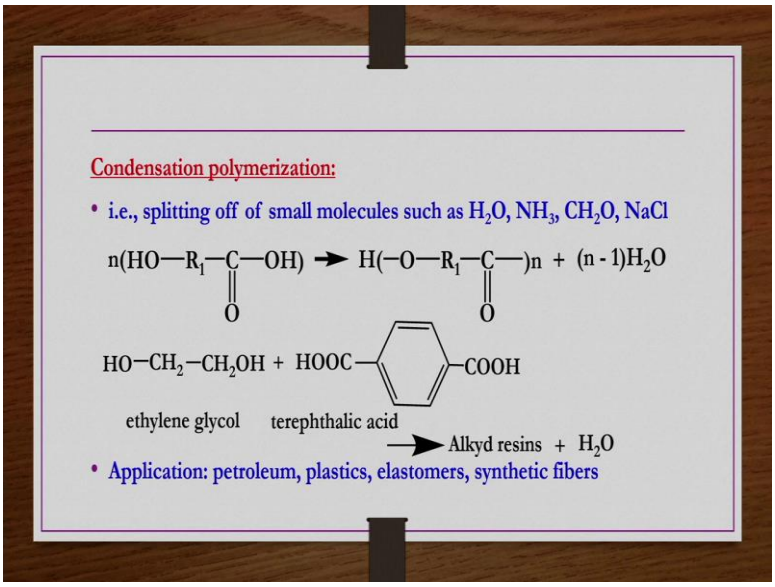

Then condensation polymerization it is nothing, but splitting of small molecules such as H 2 O, NH 3, CH 2 O, N a C l etcetera for example, you have ethylene glycol and terephthalic acid if you react them together then you can get alkyd resins and then water. So, these are very common in petroleum plastics industries synthetic fibers productions etcetera.

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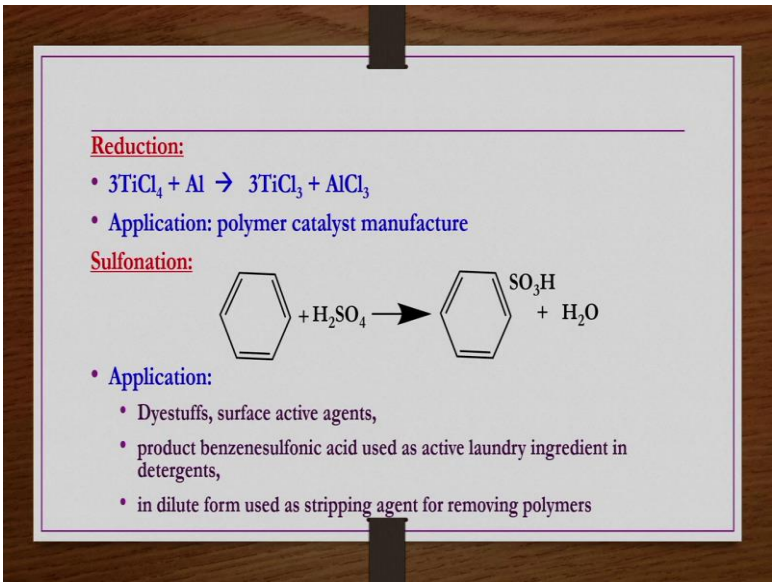

Then reduction reactions one example of reduction reaction is given here 3 T a C l 4 plus A l is giving 3 T i C l 3 plus A l C l 3 which is a reduction reaction polymer catalyst manufacture because these are often used as a catalyst in polymeric industries. Sulfonation reaction if you react benzene with sulfuric acid then you get benzene sulfonic acid as a product which is used as surface active agent dyestuffs etcetera is also used as active laundry ingredients in detergents etcetera.

It is also used as a stripping agent for removing of polymers in polymeric industries.

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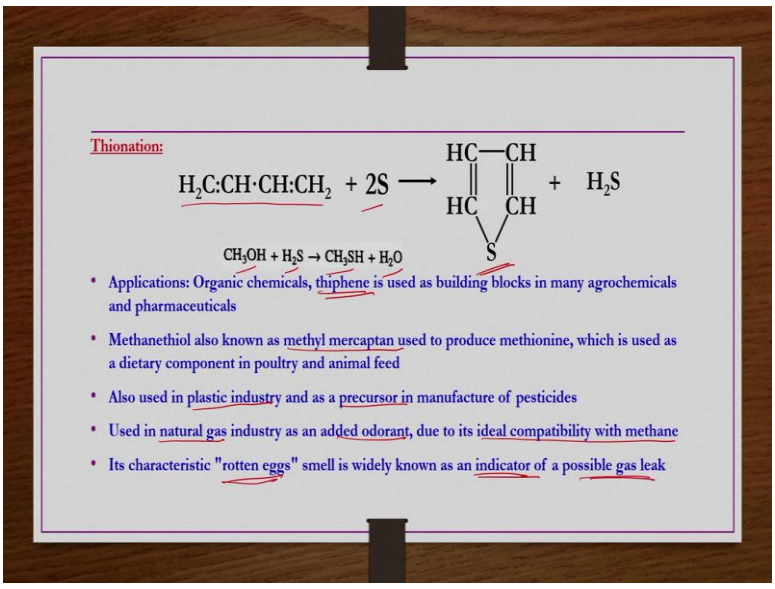

And then finally, one more reaction now with this reaction we are going to wind up the unit processes thionation reaction let us say if you have a this component and then reacting with the sulfur then you can get thiophene as a component. Similarly, let us say if you have a methanol you react with H 2 S then you get methane thionyl as a product plus water you can get ok.

Now, these are like this thiophene in general used as building blocks in many agrochemicals and pharmaceuticals industries, methane thiol is also known as methyl mercaptan and used to produce methionine which is used as a dietary component in poultry and animal feed.

It is also used in plastic industry and as a precursor in manufacture of pesticides used in natural gas industry as added odorant, due to its ideal compatibility with the methane. It is also having the characteristics of rotten eggs and then this smell is often used as a indication of a possible gas leakage in production of these chemicals in general.

So, we have seen a few examples of unit processes, in the next class we are going to discuss basics about a few unit operations as well.

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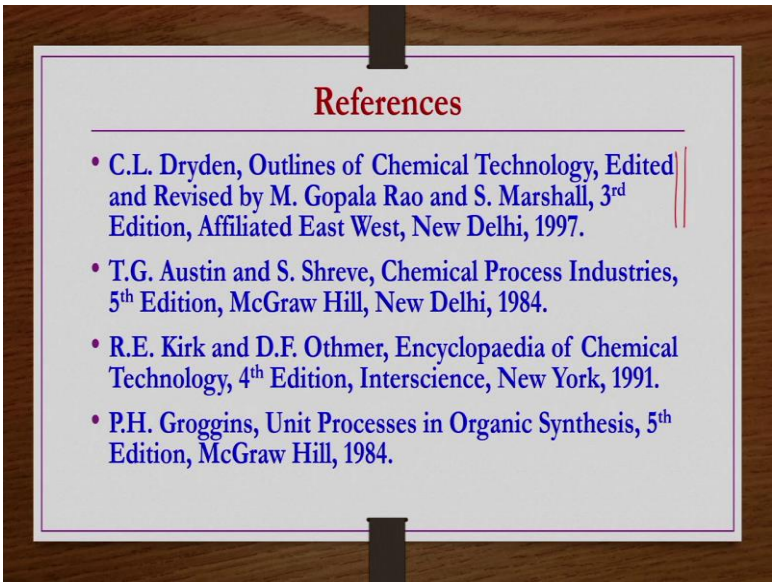

The references for today's lecture are provided here. So, most of the lecture details you can find out from this book ok.

Thank you.