Science and Technology of Polymers

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Lecture - 17
Polymerization Techniques (Contd.)

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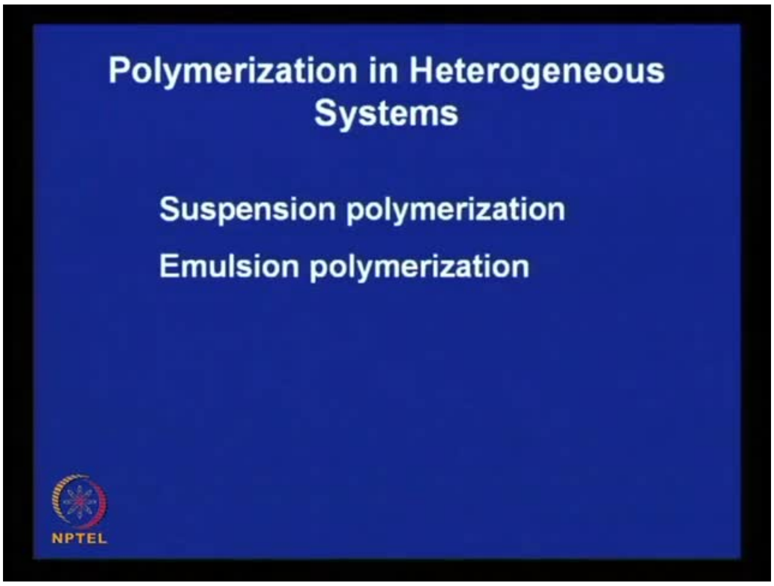

Polymerization in Heterogeneous Systems

Suspension polymerization

Emulsion polymerization

Good morning, today let us discuss about the polymerization techniques, which is in a heterogeneous system. Heterogeneous system means, it is heterogeneous from the very beginning. In case of bulk polymerization you have seen it is homogeneous, in case of solution polymerization you have seen it is homogeneous system, and this heterogeneous system means the monomer, monomer and the polymer; both are insoluble in the polymerization medium.

In order to overcome the problems encounter during the synthesis of polymerization by bulk technique or solution technique even in both those cases, both of those cases there are problems, so you have to overcome those problems. The suspension polymerization or emulsion polymerization techniques are followed which is, which are heterogeneous in nature from the very beginning of polymerization. Because the monomer, which is technique here, monomer is not soluble in the polymerization medium that means from the term suspension from the term suspension.

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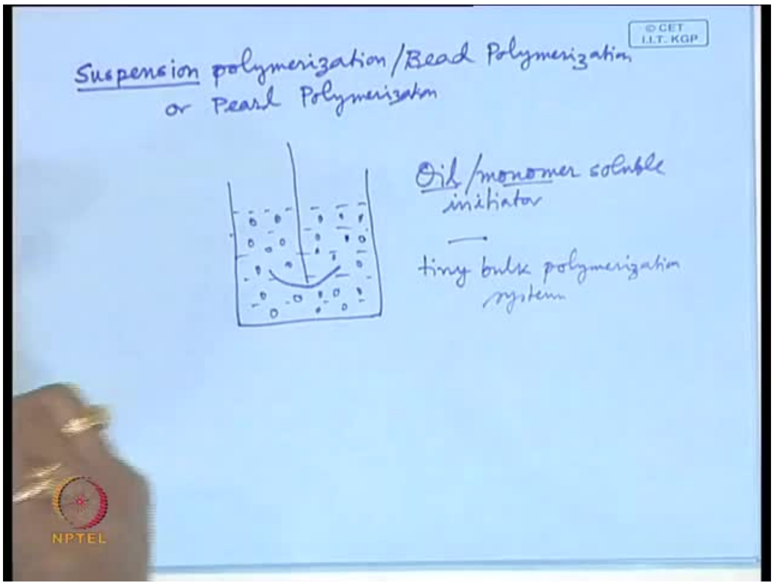

Suspension polymerization/Bead Polymerization or Pearl Polymerization

Oil/monomer soluble initiator

tiny bulk polymerization system

You see, suspension as the monomer is kept suspended in a dispersion medium. Here the dispersion medium is water, so are monomers are organic in nature, hydrophobic in nature. So, hydrophobic monomer when it is suspended or dispersed in a aqueous, in an aqueous phase and it is allowed to polymerize by free radical chain polymerization principle, we get the suspension polymer by the suspension polymerization technique.

That means in the container, in a container you take water to the dispersion medium. There you add the monomer being hydrophobic in nature, organic in nature. It will not be miscible with the water phase so it will forming different organic phase and under if it is kept under recitation (( )), so it will form droplets. Organic monomer droplets dispersed in this medium and here the initiator is taken as oil or monomer soluble initiator. You know in this is a case of addition check polymerization, here we need monomer and initiator in case of bulk polymerization, you saw that there was no solvent, no other things, no dispersion medium, nothing there.

If you add monomer initiated to the monomer it gets dissolved, then by thermal, your decomposition of the initiator it starts polymerization and polymer growth occurs and we get the polymer and in case of solution also here the monomer is solvent. There also initiator is also solvent in the polymerization phase, solution phase. In case of suspense of polymerization since monomer is organic in nature it is it is actually suspended, kept suspended by hesitation, studying. So, we will find that these monomers formed droplet it define suspended within the medium. So, here in this case you have to carry on the polymerization it is expected that the initiator should be present in the monomer phase that means within the droplet. That is why it is written oil or monomer soluble initiators, same benzoyl peroxide as initiator if you take. Here you take water add monomer it will form a different layer then you start hesitation. So, that layer will be broken to form droplets so suspension of monomer droplets will be there in the aqueous medium. Then you add the initiator and since initiators is also organic compound it will go to the monomer phase that means it will remain dissolved in the monomer droplets.

So, each droplets can be considered as a tiny bulk polymerization system. We do not have any problem to accept this hypothesis, monomer remains dissolved in the suspended monomer droplet, clear. Monomer remains soluble in the suspended monomer droplet, not in the water phase. So, here are two phase organic phase which is suspended or dispersed in the form of small droplet, where the droplet size is bigger than 10 to the power minus 4 centimeter, the droplet size of the monomer is bigger than 10 to the power minus 4 centimeter. If you add the all soluble initiator, that initiator will go to the monomer droplet. So, it will be dissolved in the monomer droplet because that initiator is not soluble in the aqueous phase, is it clear now.

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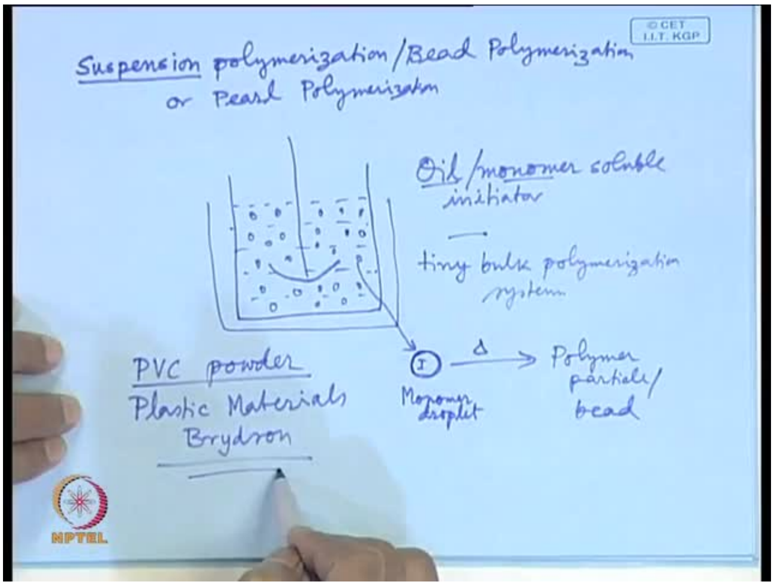

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or Pearl Polymerization

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tiny bulk polymerization
system

PVC powder
Plastic Materials
Brydron

So, each and every droplet, suppose I am showing it in the separate way this is the monomer droplet, it contains the initiator. Now if the system is heated to the decompose initiator that means if the initiator achieves the decompose, the temperature. Initiator will decompose to form free radicals, surrounding this free radical there are monomer within the droplet so that will gradually convert this monomer droplet to monomer particle, a polymer bead, any problem, polymer bead, polymer particle this same monomer droplet. So, I am showing this monomer droplet in a bigger dimension, so it contains initiator initiator decomposes so long the monomer is present over there. These initiators have a molecule sub initiator present within this monomer droplet that will be converted to polymer solid polymer particle.

So initially it is actually a liquid liquid droplet, that liquid droplet will be converted to solid polymer particle by this initiator present over there. Since it looks like bead it is called bead polymerization because this suspended monomer droplet is converted to polymer particle, polymer bead like spherical polymer beads or it looks like cordless that is why it is called cord polymerization. They had the advantages they had the advantages I told, I told that each and every monomer droplet bears like a tiny bulk polymerization system.

So, we are getting the advantage of bulk polymerization system in a mini immersion. So, the amount of heat generated amount of heat generated within the small droplet that will be dissipated through this aqueous phase. So, water will take out the heat, since it is under agitation and if this system is in a thermostatic bath or in a or fitted with a system for heat transfer through this wall. So, heat will be remove and the problem of that auto exhilaration, run away actions are all those are avoided.

Now one questions comes, how we can keep this monomer droplets suspended. So, for that we should need a suspension stabilizer suspension stabilizer. That means if you, if you stop the agitation or if the agitation is not adequate enough then what will happen. It will not form smaller droplets. Once it form smaller droplets, if those droplets are surrounded by something which you prevent the collisions of merging of individual droplets. To again to form a layer then it will maintain the suspension of the droplets within the aqueous phase so and then after supplying heat it will all, the droplets will start polymerization inside the droplet by this initiator.

So, all the droplets will be converted to polymerization so we can carry out the 100 percent polymerization. Here there is a limit of polymerization, after to say 30 percent, 70 percent, 80 percent like that. So, we can carry out up to 100 percent polymerization because the heat transfer problem is not there. Here the heat is transfer from the monomer droplet to the aqueous phase and from the aqueous phase to the cooling system. So, it can provide better control of polymerization.

We can get 100 percent conversion in one, your batch in one time your entire monomer can be converted to polymer with minimum or no residual monomer present within this system, do you understand. So, whatever monomer is taken within the reactor that monomer can be entirely converted to polymer and since it gives proper or and better control. So, we can have a better control over molecular weight, we can have a better control of over molecular distribution, we can have better control over microstructure of the polymer which has been found within this beads all right.

But there is also again a problem each and every system has some merits and demerits. The demerits of this process is that after this polymer particles are formed, it is to filtered washed and dried etcetera. That is not actually problem again, but the the product which will obtain from this thing or polymer particles or beads or pearls like part like polymer, beads. Which are available, which will be obtain from this process so that will be contaminated by this suspension stabilizers and other things that may remain with that thing.

So, it is a contaminated polymer so purest form or pure form of polymer may not be available from this thing because yes it is possible, but it has to pass through, it has to stringent purification steps so that the impurities are remove. These suspension stabilizers and other additives which are used during this polymerization, so those can be removed by purification and that will incur higher cost.

Anyway still then suspension polymerization is is a good process. Say PVC powder PVC powder, this PVC powder is made by this suspension polymerization process, polygonal powder made by this suspension polymerization process. Now you can your effort to consult a book, these book plastic materials by Brydson. There you can see details of manufacture or polymerization techniques, this suspension polymerization technique. There with some sketch of is to your reactors, also there you can see, please go through this book.

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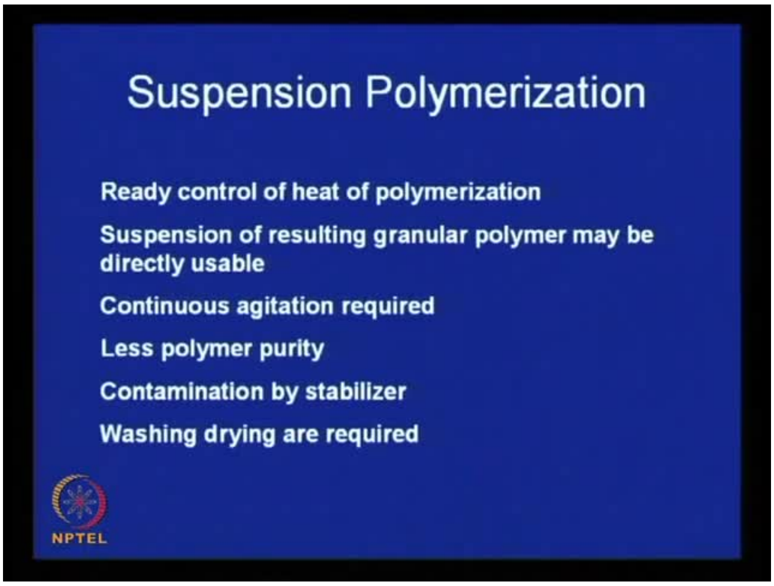

Suspension Polymerization

Ready control of heat of polymerization

Suspension of resulting granular polymer may be directly usable

Continuous agitation required

Less polymer purity

Contamination by stabilizer

Washing drying are required

So here you see, these are the characteristics shown these are the characteristics shown over here, ready control of heat of polymerization. As I already said suspension of resulting granular polymer may be directly usable, that means sometimes suspension can be directly used or if it is filtered you can get particles isolated. Waste and dried continuous agitation is required, less polymer purity contamination by stabilizer washing drying etcetera are required.

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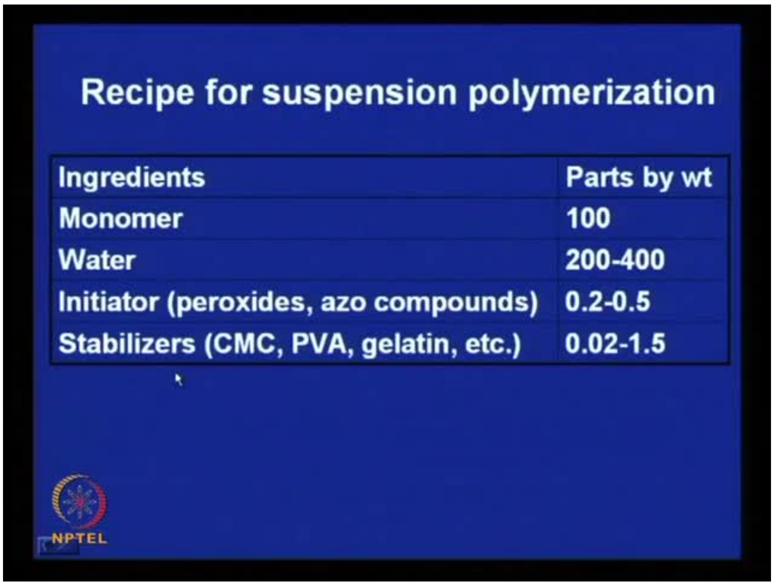

Recipe for suspension polymerization

Ingredients	Parts by wt
Monomer	100
Water	200-400
Initiator (peroxides, azo compounds)	0.2-0.5
Stabilizers (CMC, PVA, gelatin, etc.)	0.02-1.5

Now look at the recipes for suspension polymerization in general. So, these are the ingredients are monomer, water, initiator, stabilizer. This is suspension stabilizer you know initiators are peroxides as a compounds peroxides as a compounds and stabilizers are carboxy methyl cellulose, CMC, carboxy methyl cellulose. PVA, polyvinyl alcohol, carboxy methyl cellulose is water soluble polyvinyl alcohol. Water soluble gelatin is polymer obtain from animals so this is also water soluble. So, this polymers actually helps stabilization of the suspended droplets in aqueous phase.

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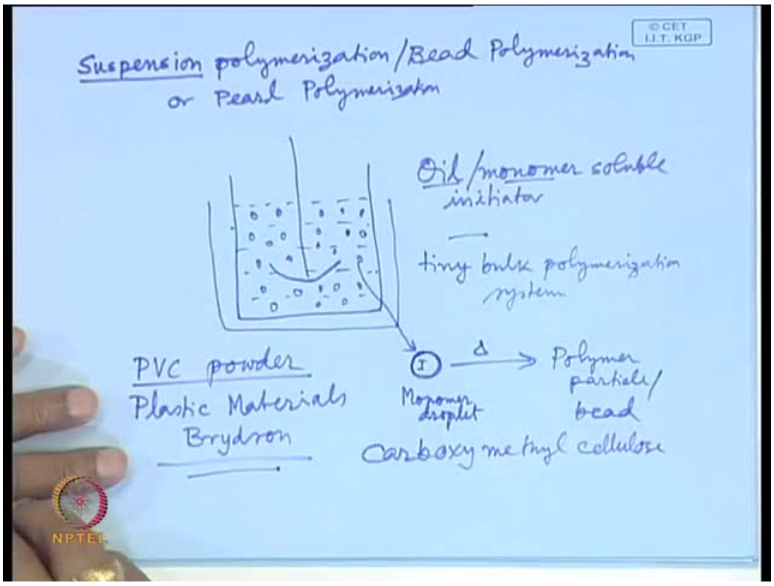

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Carboxy methyl cellulose

Carboxy methyl cellulose carboxy methyl cellulose, PVA, polyvinyl alcohol again. Here is a science if you are interested, you can think of science means this is suspension suspension of organic phase, organic droplet suspension of organic droplet in aqueous phase. So, there is an interface of hydrophobic and hydrophilic. Hydrophobic, hydrophilic inter phase is there so that is always unstable because of this energy surface. Energy now that can be stabilized if at the inter phase there is a component which is having hydrophobic and hydrophilic to satisfy the both of the inter phases.

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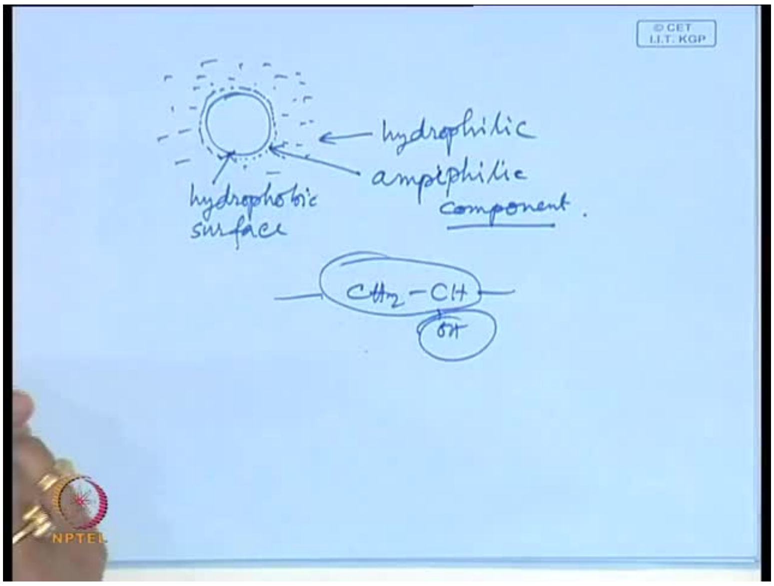

So this is the, suppose this is a droplet this is a surface is hydrophobic and outside is, outside endowment is hydrophilic hydrophilic. So, here if some, some layer is present over this hydrophilic surface this is you can say an ampiphilic, ampiphilic component. What is ampiphilic, having both hydrophilic and hydrophobic. So, towards hydrophobic, that hydrophobic side will be oriented and hydrophilic hydrophilic side of this ampiphilic component will be there. So, these are actually nothing but same gelatin this are ampiphilic component, PVA. What is PVA? So, this is hydrophobic this is hydrophilic, like this.

So, this way this stabilizes, stabilizes suspension even if some there is some alteration in speed this suspension will not up it will remain stable. That is the beauty of this technique. Is ampiphilic, hydrophobic and hydrophilic. Hydrophobic means water repelling, hydrophilic mean water attracting, water friendly water friendly hydrophilic, water repelling hydrophilic. Phobia, you know the meaning of phobia. Phobia, you have phobia on, on me, not feeling phobic. You are phobic to me, I am philic to you this is the problem okay.

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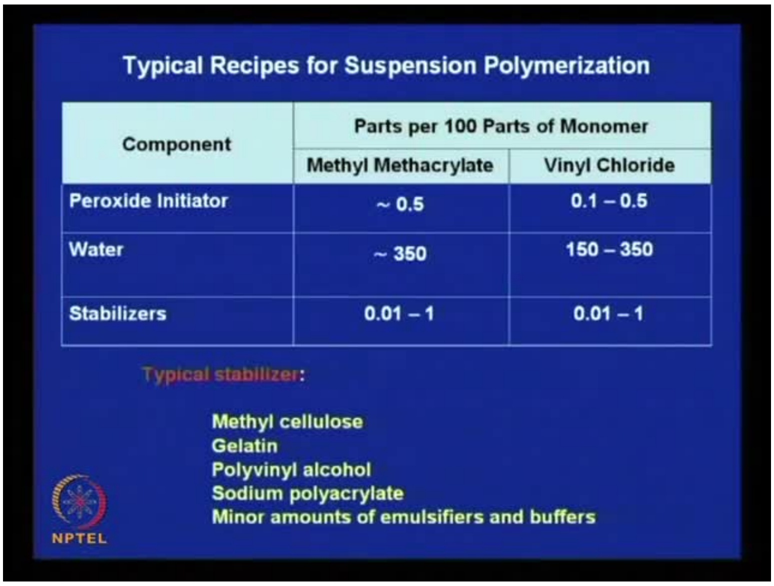

Typical Recipes for Suspension Polymerization

Component	Parts per 100 Parts of Monomer	
	Methyl Methacrylate	Vinyl Chloride
Peroxide Initiator	~ 0.5	0.1 – 0.5
Water	~ 350	150 – 350
Stabilizers	0.01 – 1	0.01 – 1

Typical stabilizer:

- Methyl cellulose
- Gelatin
- Polyvinyl alcohol
- Sodium polyacrylate
- Minor amounts of emulsifiers and buffers

Another recipe for suspension polymerization. Please put your attention, recipes for suspension polymerization, methyl methacrylate, vinyl chloride, very simple. Your composition or the recipe, you know what is called recipe ingredients and their amounts of a system. Say food menu, for food menu on particular menu there is recipe means you have to take some carbohydrates, some protein, some sugar, some salt, some pepper something like that.

So these are the ingredients and the total ingredients and the components total mixer is the recipe. If you know the recipe you can cook a good menu provided you know the conditions and your workmanship is good. So, we have peroxide initiators, water, stabilizers, these are the monomers. So, look at this amounts say more than 1 8 8 180 to 200 parts of water is used, per say 100 parts of monomer. If you take 100 parts of monomer say, 100 gram of monomer, you have to take minimum 180 to 200 or 250 or 300 parts of water. There you sustained at the initiator that will go to monomer phase, not in the, that will not remain in the aqueous phase and if we form a polymer, the easiest simplest technique.

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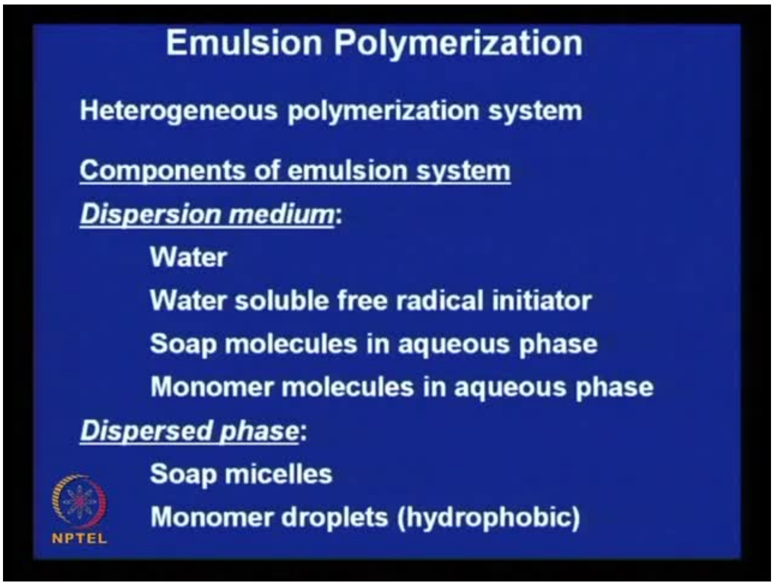

Emulsion Polymerization

Heterogeneous polymerization system

Components of emulsion system

Dispersion medium:

Water

Water soluble free radical initiator

Soap molecules in aqueous phase

Monomer molecules in aqueous phase

Dispersed phase:

Soap micelles

Monomer droplets (hydrophobic)

Then, this is most important emulsion polymerization technique. Majority of the polymers of today today are manufactured by emulsion polymerization technique because the emulsion polymerization can be carried out at lower temperature and lower temperature. As well as the polymerization, the control over polymerization kinetics are better than the other polymerization techniques, emulsion polymerization technique. Can you give, tell me, example of one emulsion. Milk, emulsion of milk is emulsion of fats and protein. Can you tell me naturally occurring emulsion other than biometrical system, natural rubber latex produced by what is the name of the plant, hevea brasiliensis hevea brasiliensis.

So, that emulsion means latex is produced by nature by natural bio synthesis of high molecular rate that remain in aqueous phase, water phase along with some proteins, lipids, carbohydrates and other sugars, soluble sugars, that is stable emulsion, but when it comes in contact with air, what happens. It starts coagulation and devaluation by bacterial attack. Once bacteria attacks occurs over there, so it becomes acidic, so that takes it to acidic pH, below seven. Gradually and ultimately coagulates. That is why immediately after this latex is taken out from the hevea tree it is stabilized by ammonia and the pH is kept above seven, in the alkaline range.

So, this latex or the emulsions are stable in alkaline pH and what is emulsion. Emulsion is again, you can say is a fine dispersion of some component, any medium, no dispersion medium or continuous phase and the size of dispersions. They are smaller than that found in suspension polymerization that means this is smaller than 10 to the power minus 4 centimeter, bigger than 10 to the power minus 4 centimeter, it form suspension smaller than 10 to the power minus 4 centimeter, it is, it forms emulation.

Here also the same problem of stabilization of the emulsified droplets or emulsified particles in dispersion medium is present, the problem is present. That means once we stop the agitation it will separate to two phases, organic phase and aqueous phase. So, when we put some oil in water, what happens, it forms layer. If you stir or sake it, agitate it, what happens, it forms emulsion. You put some vegetable oil in water, shake vigorously this way, shake vigorously, what happens. It becomes whitish milky like why, that oil droplets brakes in to smaller droplets, bigger droplets brakes into smaller droplets and it looks like, since there is some interphase created hydrophobic and hydrophilic inter phase created, actually, that so this kind of optical property, alright.

Now, that is to be stabilized, how it is stabilized. In case of suspension polymerization stabilize was done by adding suspension stabilizer, what are those stabilizers carboxy methyl cellulose, polyvinyl alcohol, gelatin, that means auto soluble ingredients which are having little hydrophobic character and hydrophilic character. So that stabilizes one suspended droplet form coalescence with another droplet, surrounding it or closed it at the vicinity of it.

Here just, you can also, if you extend this suspension system, only the size is smaller enough, small enough, you can call it an emulsion and these are droplet also stabilized here. Here also the droplets are stabilized. How these are stabilized, defiantly there must be some stabilizers. Now, you have seen if you put some soap in water, stir it, try to dissolved it and stir it, what happens. That soap solutions becomes looks like milky, why it looks like milky because it form certain emulsions. So what are the soaps? The soaps... What are the consignation? What are the molecular nature and there confutations this soaps.

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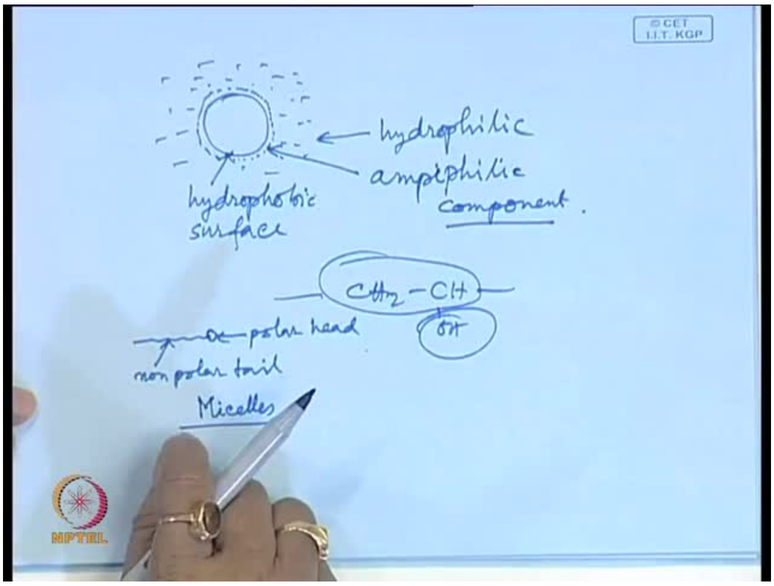

Soaps are nothing but some molecules having a polar sight, polar head and non-polar tail, polar head and non-polar tail, is soap. Say, soap of some fatty acid, sodium salt of some fatty acid. That is soap because how soaps are made, fatty acids are taken from vegetable oils, there is (( )) so the soaps are formed. Now, when you add the soaps to water, what happens, it forms, it shows milky suspension something like that because they form some aggregates of the soap molecules to the certain geometry some defined geometry, they are called micelles.

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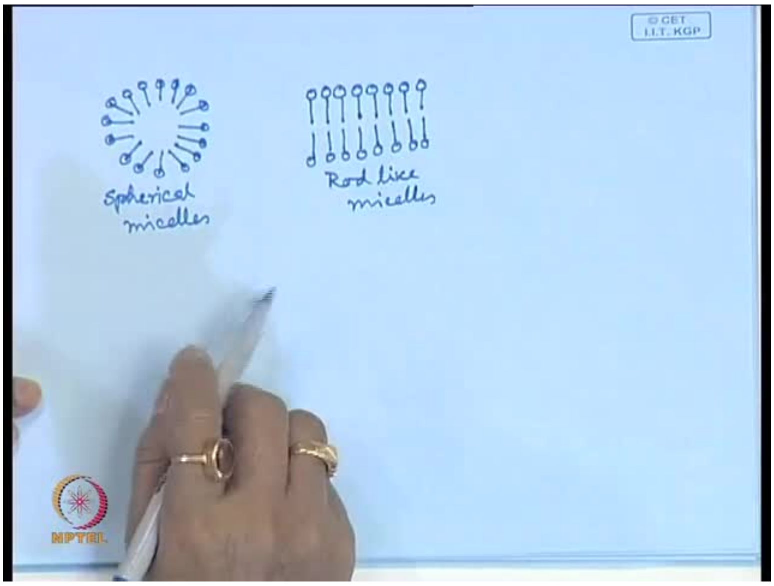

Micelles are formed, what are those micelles, say if you add soap molecules to water it can formed aggregates like this, as I am drawing. These are fatty acids, sodium salt of fatty acids suppose or sulfonates, organic sulfonates or detergents. These molecules can form aggregates like this geometry or it can also form geometry like this. So this is spherical aggregates, spherical aggregates, this is rod like aggregates these are called micelles. So, in case of emulsion polymerization what we actually do, we add this monomer in aqueous phase. Monomers are organic nature, so organic phase you want to disperse that organic phase in water, how it can be done, by agitation with the help of mechanical stirring, mechanical agitation.

We can break that organic layer into smaller droplets or fine droplets in aqueous phase, what is stop the agitation, it will again to form to it will separate into two layers, organic layer and aqueous layer. Right now once you break this layers into dispersion of organic droplets in water and if you can stabilize then then that will remain as you have seen in case of milk, how milk is coagulated, we add some acid or salt. If you put some salt in milk, milk is coagulated. If you put some acid, we deliberately put some acid, forgetting what is that called, what we get after coagulation of milk, curd. What is called, find out, rasagulla. Rasagulla is not directly obtain from your, paneer that is another name, other than paneer. He is little clever by passing the actual term, anyway, so why it actually coagulates.

That means if this salts or acids are added, discharge over the emulsified particle is actually utilized by some high link exchange offer electrolytic effect, then it coagulates, organic phase coagulates there. Now, we are going to study this emulsion polymerization system. Here also what we do, we add monomer in water. Water is dispersed, dispersion medium dispersion medium, in that dispersion medium we put monomer that is organic in nature. Now, to stabilize the monomer droplets formed by mechanical agitation we add soap molecules. Now, when we add soap molecules the soap molecules foam will form. These spherical aggregates, this is the hydrophobic side, hydrophobic till and hydrophilic head.

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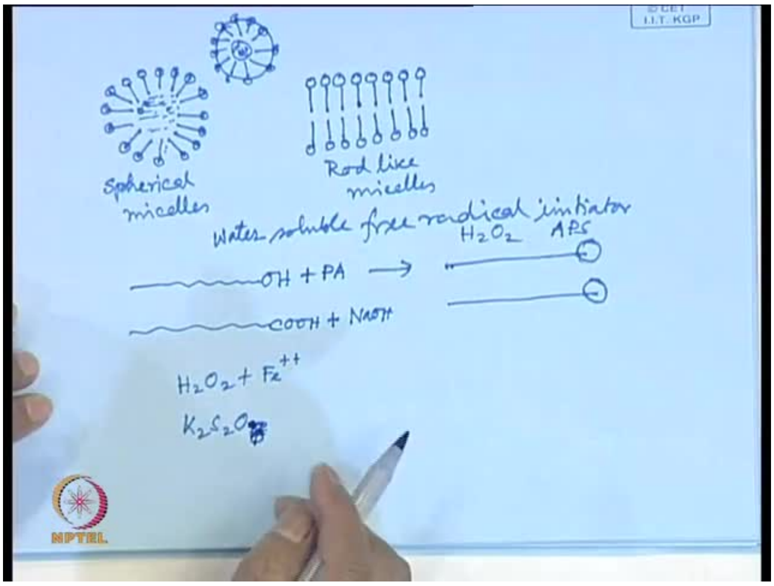

Say oil supply glyceride fatty acids or you take a fatty alcohol fatty alcohol or you take a fatty acid. Now, this fatty alcohol can be reacted with some phosphoric acid phosphoric acid or it can be reacted with some alcoholic, say sodium hydroxide. Both of them will form, this will form phosphate ester and this will from some sodium salt. So, this part this part, ester part will form this polar head and this salt part will form the polar head in case of this fatty acid soap.

So, these are used for making, forming micelles, here aggregates. Either in this spherical form or rod like form or both can be present in the system. What happens, since this is hydrophilic zone, core core is sorry. Core is hydrophobic so here this monomer, monomer phase can this side comfortably. If there is another micelle close to this, if there is another micelle, is hydrophobic surface, hydrophilic surface inside there is a core, there monomer is there.

So, this this monomer, this monomer cannot come closer because of the presence of this lipids, lipid molecular. these are actually lipid like, these micelles or soaps or called lipid like molecules, lipids is sometimes, lipids can also be directly taken. So, these are the, so these two cannot (( )), because this is polar, this is polar inside the core there is monomer. So, this is a system now you want to polymerize this monomer trapped inside this micelle, for this we need initiator molecule. In case of suspension polymerization we deliberately added some initiator like benzoyl peroxide as (( )) all this thing or (( )) hydro peroxide (( )) peroxide, these things. So, those gets soluble in the monomer phase in the suspension polymerization, so their suspended monomer droplet is converted to a polymer particle. Here, what is the kind of monomer initiator we can use if we add, if we add benzoyl peroxide or this emulsion polymerization cannot be done. For that we need water soluble free radical initiator, can you tell me one example water soluble free radical initiator, anything more, anything else.

Water soluble initiator, you have been researching polymer you do not know, ammonium persulfate ammonium persulfate, redox system, redox initiator. Who can say redox initiator, as you if your following from haven, your falling from haven, redox initiator, example of redox initiator, who can say. Have you not see this system, did I not show you, did I not show you. Persulfate or what a perasulfate, k 2 s 2 o 7, 8.

So, potassium para sulfate, hydrogen peroxide perasulfate. These are redox initiators, redox initiators are soluble in water. So, in case of this emulsion polymerization technique, you have to select is suitable water soluble initiator. Then water soluble initiator remain present in the aqueous phase, monomer in the, within the micelle and that gives you emulsion polymerization or polymer by emulsion polymerization technique, where is reason, where is reason.

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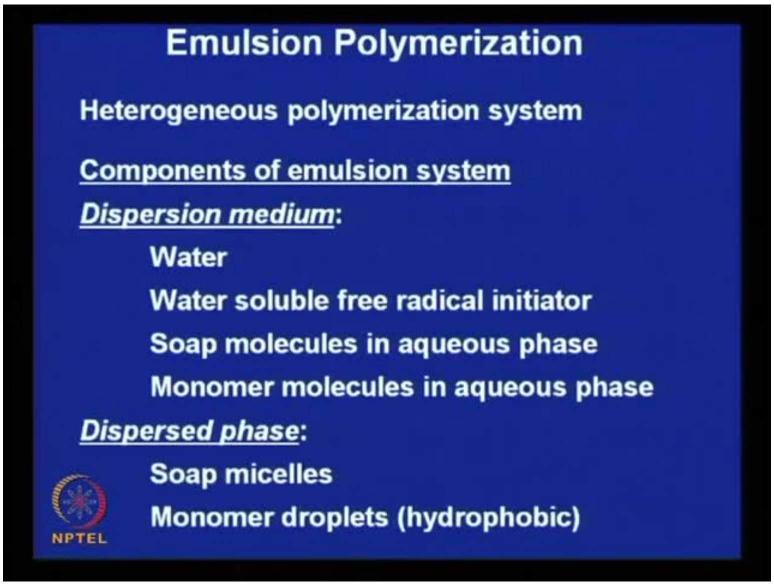
Emulsion Polymerization

Heterogeneous polymerization system

Components of emulsion system

Dispersion medium:

- Water
- Water soluble free radical initiator
- Soap molecules in aqueous phase
- Monomer molecules in aqueous phase

Dispersed phase:

- Soap micelles
- Monomer droplets (hydrophobic)

So you have already read what is shown over here, components of emulsion system. Water is dispersion medium, in the dispersion medium it contains water soluble free radical initiator, it contain soap micelles in aqueous phase. Soap molecules in the form of micelles in aqueous phase, monomer molecules in aqueous phase also that means some soap molecules remain soluble in aqueous phase other than micelle (( )).

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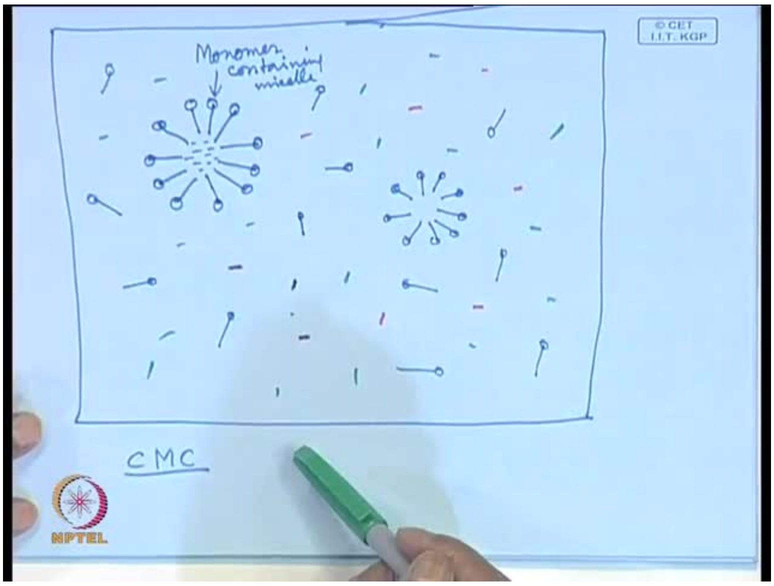

Now, let us concentrate or attention to an emulsion polymerization system that is assume that is contains a spherical micelle or you can assume a rod like micelle also, of course. The distance between or the dimension of this core, that is also defined that can also be defined by or the space between a rod like micelle, the core space between the rod like micelle micelle aggregates which are also fixed, look at the book there the domains are given 50 angstroms 50, 50 two 60 angstroms, length of the rod might be 100 angstrom, diameter of the micelle may be 100 to 150 angstrom. So, those things are written there, you take it from book.

Now, in in emulsion polymerization system. First some soap molecules are added to water then agitation is started, what happens. Soap will be dissolved and some soap molecules will for aggregates and some soap molecules will remain in the aqueous phase. Suppose, this is the system a container is present, the soap molecules are there randomly dissolve soap molecules and that means, if if the concentration of the soap process a critical level then only it will form micelles. If you add small quantity of soap that will be dissolved like this, if the concentration exceeds certain critical concentration then only the soap molecules will form micelles that is called CMC, critical micelle concentration, critical micelle concentration.

So, we have to take the amount of soap will such a quantity so that it forms large number of micelles of such kind, you understand. Then we add monomer or we can add both this monomer and emulsifier molecules or some soap molecules simultaneously. What will happen as soon as you at the monomer and soap micelles and start the agitation then fine droplets some monomer will be found and eventually those monomer droplets will be in enveloped, covered by the soap molecules like this.

So, we can assume that inside this micelle there is monomer molecules present so this is a monomer containing micelle. Now, there can be soap micelles which may not contain the monomer, simple soap micelles may be there, if the concentration of the soap molecules are beyond this CMC. So, in this polymerization system what we have added, we have added soap and a detergent and monomer and some quantity of monomer, some very small although will remain in the aqueous phase.

Suppose this is monomer, I am writing this way, this are mono… should use other color. Suppose these are the monomer molecules, some monomer molecules because although we say the monomers are hydrophobic organic, but they have certain limited solubility that solubility may be 1 percent, less than 1 percent or it can be more than 1 percent also 2 to 3 percent or 4 percent solubility of monomer in aqueous phase. So, after adding monomer to this thing will get monomer in 2 phases, in organic phase, here within the micelle and in the aqueous phase in dissolved condition, understand. Then what we add, we add the initiator molecules, because initiators are auto soluble. Suppose we add hydrogen peroxide, persulfate or potassium persulfate, 2 s 2 o 8, potassium persulfate.

So, there will be some initiator molecules that remains dissolved in this system. Since this is redox system, what happens, this redox initiators can be compose at a ambient temperature or lower than ambient temperature. It can produce free radicals at 5 degree, 5 to 10 degree Celsius and as well as it can produce radicals at 30 to 50 degree Celsius temperature also. Whereas, if you take danger peroxide or eyebeam you have to heat beyond 50, 60 degree Celsius temperature otherwise those will not produce radicals, but this, water soluble redox initiators that can, those can produce radicals at lower than the peroxide initiators, temperature than the decomposition temperature of peroxide initiators.

So, what have, what is happening there, is very interesting. So, these initiator molecules, say hydrogen peroxide perasulfate that will form OH free radical, you know that reaction. Hydrogen peroxide perasulfate react form OH ion, OH free radical and becomes ferric, ferrous become ferric. Ferrous is converted to ferric and hydrogen peroxide converted to one say OH radical or as well as OH ion radical ion.

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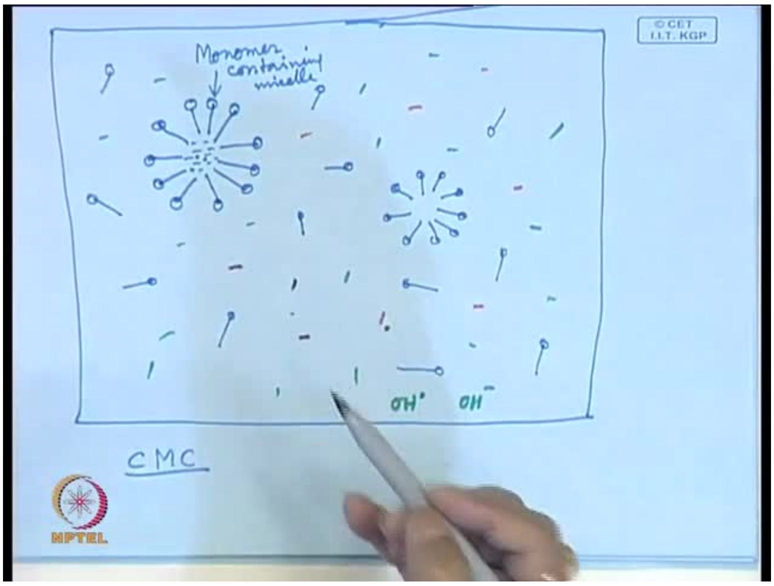

Now, this OH radical being tiny in size, what it does? It enters this core at the monomer is available, monomer is there as well as it is also present here. So, whatever radicals produced in the aqueous phase, it also contain some dissolve monomer that can initiate this monomer, initiate this monomer, which are the monomers red color, so this green dot can initiate this monomer once it initiate the monomer, some polymer is initiated in the aqueous phase, try to understand.

Some polymer is formed in the aqueous phase, initiated polymerization is initiated the aqueous phase. Gradually it will attract more and more monomer or it will interact with more and more monomer. So, it will continue propagation step. Through the propagation step that growing’s and radical will growing bigger and bigger and bigger, as it grows bigger, what happens becomes hydrophobic. Once it becomes hydrophobic due to growth of this free radical size what will happen. You will try to phase out, come out of the aqueous phase eventually soap molecules are there, like friends they will cover it. So what will happen, we consider that, I have to show that other way.

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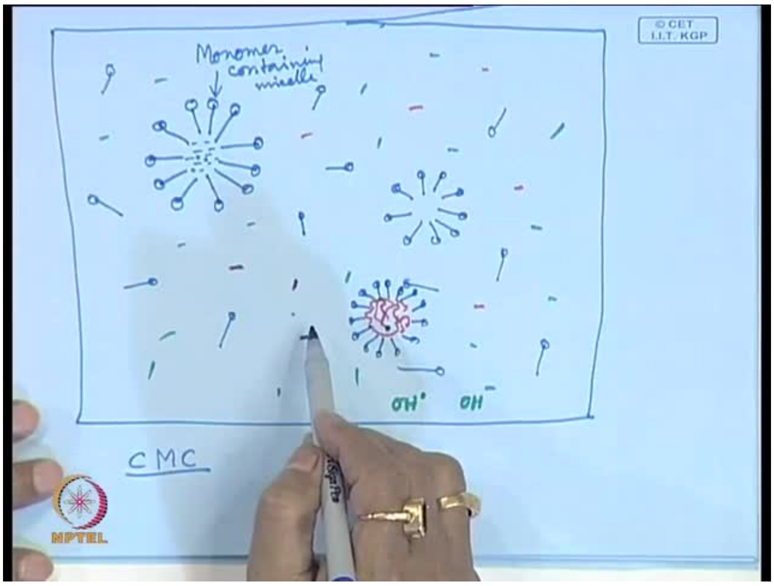

So, here it is being polymerized so what happens, polymer chain will grow, getting bigger and bigger. Eventually what happens this will be stabilized by soap molecules, covered by, envelop by soap molecules. So, this polymer this polymer radical is stabilized by soap molecules, where from these soap molecules will come. These are present in the aqueous phase, soap molecules from the aqueous phase will come and cover it.

Now, still it is growing so long the monomer is available within this core, how this monomer will be available because in the aqueous phase there is monomer. So, this monomer by process that will penetrate, that will go inside this system and it will continue, how long it will continue, it has to be terminated, it is to terminate. It will not terminate until and unless another radical enters there.

Now, you see there is diffusion of so many, all the components present in the system, very interesting. So, soap molecules are there discovering monomer molecules in the aqueous phase so that will go inside and also free radicals in the aqueous phase. So, one time can, one time can reach when another free radical enters and dimension will cover there. What we have getting one polymer particle of only 1, constitute by 1 molecule only and since it is covered by, this growing chain is covered by, growing free radical chain is covered by this soap micelle. The probability of entering free radical, many free radicals inside or another growing radical inside this thing becomes less. So, unwanted side reactions of transfer transfer to polymer chain, transfer to initiator, transfer to monomer, transfer to other things becomes less.

So, what happens, we can get highest or longest polymer chain or highest molecular rate and since there is minimum disturbance, here we can get the highest rate of polymerization. This is the beauty of emulsion polymerization technique which can provide highest molecular rate and highest polymerization rate, highest molecular rate and highest polymerization rate, emulsion polymerization system. So this is, I have shown only one representative isolated case from initiation to termination. I repeat once again in the aqueous phase there is monomer, in the aqueous phase there is initiator, alright. In the aqueous phase itself initiator decomposes for radical and it get access to monomer.

So, initiations occurs in the aqueous phase once initiation occurs in the aqueous phase by diffusion process monomer will arise to that initiated monomer sight. Then it continues adding on to the initiated monomer that means starting propagation, chain propagation for being bigger and bigger size of the polymer free radical. As it, time will come oven it becomes hydrophobic, sufficiently hydrophobic will to phase out, precipitate out of the system. Eventually the soap molecules are present in the aqueous phase that will cover it, envelop it like micelle and that will be stabilized.

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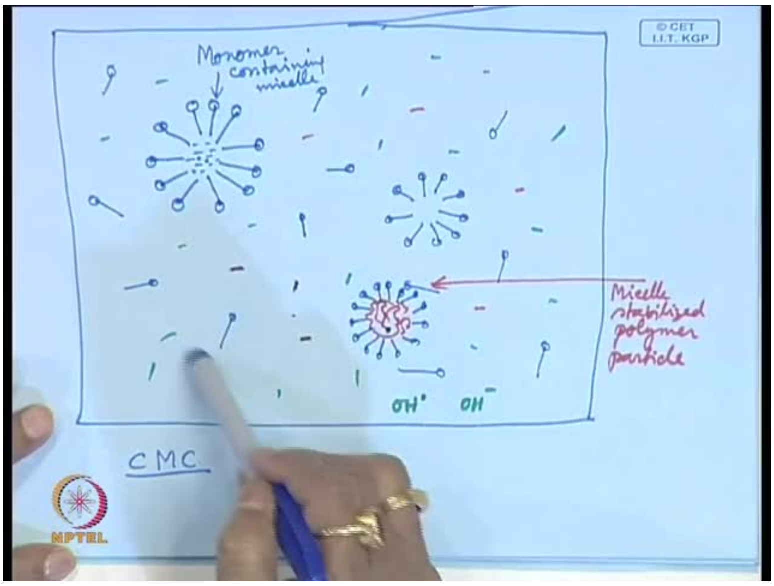

So, we can write this is micelle stabilized polymer particle, yes you had some questions. Although I showed that the monomer is stabilized by micelle, here in this system we can consider this way. There is a monomer reservoir, in polymerization plant what we see silos, reservoir contains, reservoir contain raw material, monomer, catalyst, stabilizer, everything and from those reservoir or silos, those raw materials are transported to the polymerization reactor. In the reactor all those components are mixed and react for polymer.

After the polymer is formed, that is transferred from the reactor to the unit then polymer is purified, waste dried etcetera and we get the final polymer in the form of particle or in the form of sheet etcetera. Here, the monomer is present in the monomer reserve and micelles are present in aggregates, your soap molecule are present in the aggregates and if you consider that this polymerization occurs in the aqueous phase.

So, initiation starts in the aqueous phase so there are so many sights, loci, locus, loci plural of locus. There may be so many loci where this polymerization can initiate and so many polymer particle can grow simultaneously, here I have shown overly 1 particle polymerization 1 particle polymerization, where as another particle polymerization can go simultaneously. Another particle polymerization can go simultaneously another particle polymerization can go simultaneously. So, within the system large number of particles polymer molecules can start formation simultaneously. Thank you.