Waste to energy conversion
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Lecture – 36
Tutorial on transesterification

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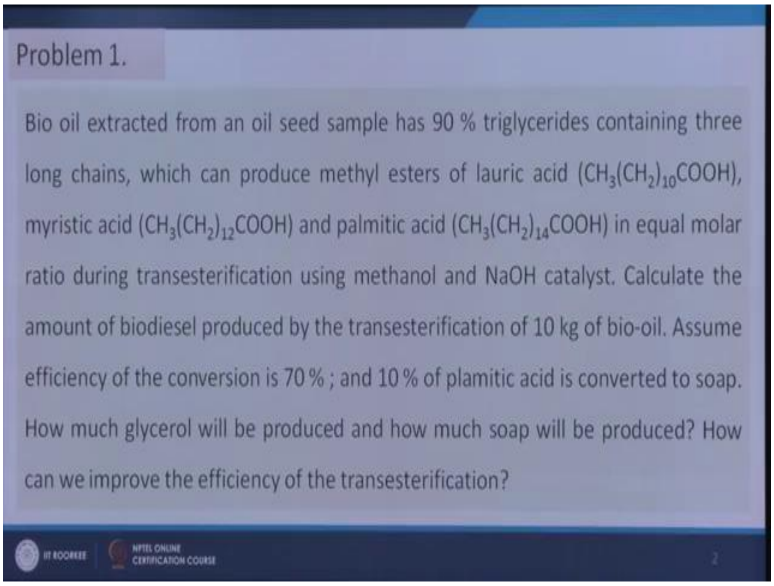

Good morning. Now, we will start discussion on a new module tutorial on transesterification. In the previous module, we have discussed on the transesterification of different types of organic waste for the production of biodiesel. And in this module, we will solve some numerical problems on this topic.

The problem number one is say bio oil extracted from an oil seed sample has 90 percent triglycerides containing 3 long chains, which can produce methyl esters of lauric acid myristic acid and palmitic acid in equal molar ratio during transesterification using methanol and sodium hydroxide catalyst. Calculate the amount of biodiesel produced by the transesterification of 10 kg of bio oil assume efficiency of the conversion is 70 percent and 10 percent of palmitic acid is converted to soap. How much glycerol will be produced, and how much soap will be produced, and how can we improve the efficiency of the transesterification process. So, this is our problem statement.

Now, we need to solve the problem. So, how can you proceed, we have 3 chains that can produce lauric acid, myristic acid and palmitic acid. So, the methyl esters of this acids will form due to the transesterification process.

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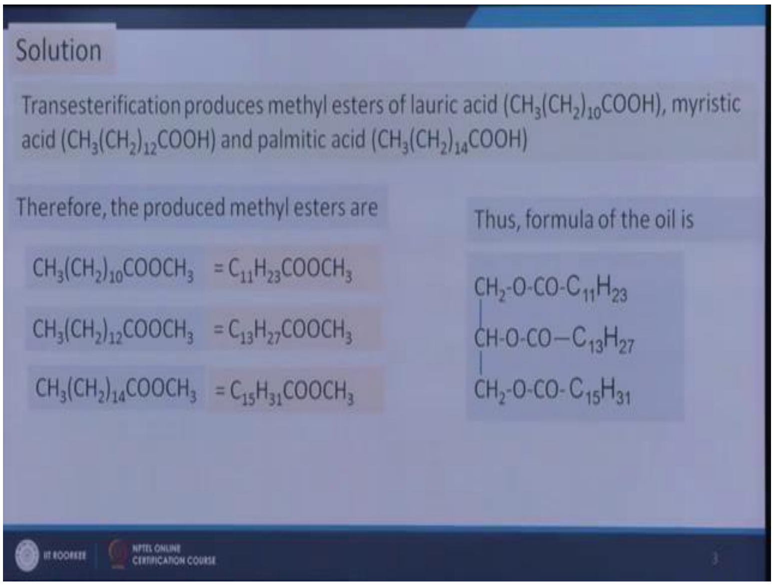

So, we will get these are the 3 biodiesel component methyl ester of lauric acid, methyl ester of myristic acid, and methyl ester of palmitic acid. So, the molecular weight of these 3 different esters are C 11 H 23 COOCH 3, and for this C 13 H 27 COOCH 3, and for this one that is C 15 H 31 COOCH 3. So, what will be the structure molecular structure of the oil which is used? So, this is the oil the formula of the oil that is CH 2 CH, CH 2-O-C 15-H 31, CH-O-CO-C 13 H 27, and CH 2-O-CO-C 11 H 23, because this is your base the tri-alcohol. Then this acids was added and then after methanol addition that these acids have been broken and they have given us the methyl esters and this tri-alcohol.

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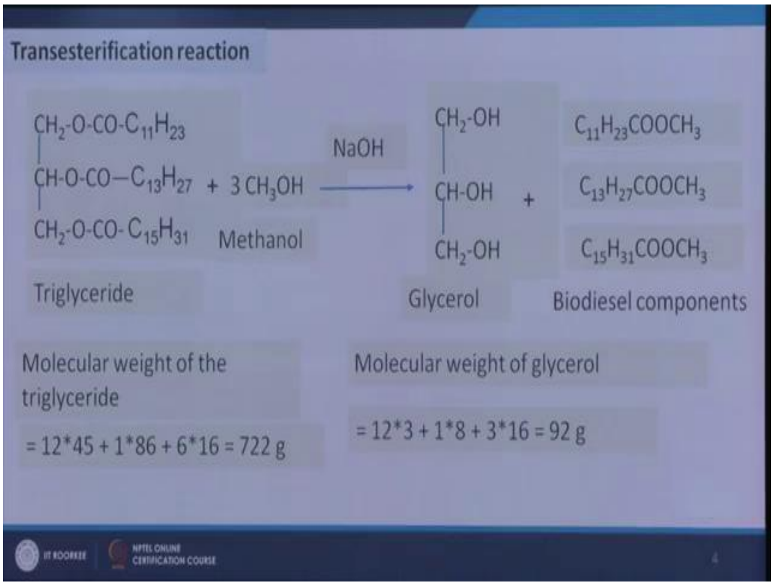

So, this is the reaction. So, this is our triglyceride, this is reacting with methanol and sodium hydroxide as the base catalyst as given in the problem statement. So, we are getting glycerol, we are getting the methyl esters of lauric acid, steric acid and palmitic acid sorry this is myristic acid and palmitic acid. So, what is the molecular weight this triglyceride. So, it has 45 carbon. So, 12 into 45 it has 86 hydrogen. So, 1 into 86 plus it has 6 oxygen, so 6 into 16. So, we are getting 722 gram the molecular weight of this one and glycerol molecular weight is 12 into 3, 3 carbon is there, and then 1 into 8 - hydrogen number is 8, and then 3 into 16, oxygen is 3, so 92 gram. So, now we are getting the molecular weight of this triglyceride and molecular weight of the glycerol.

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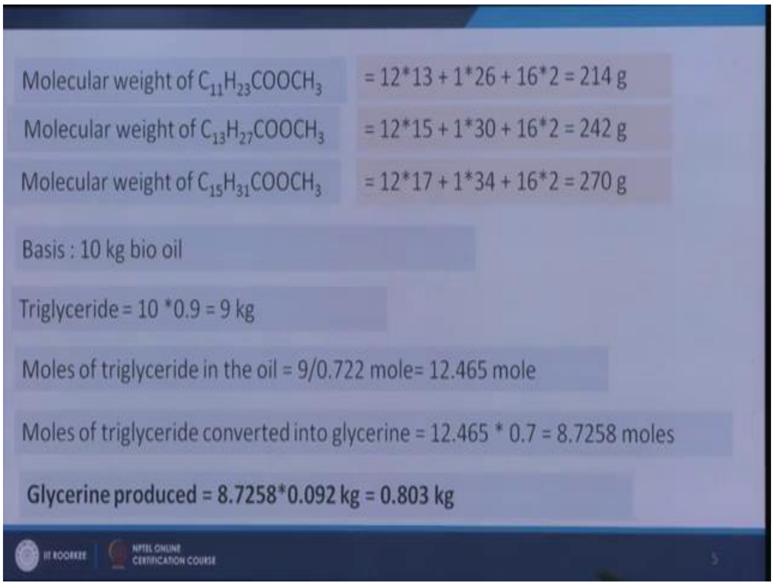

Then what we will see, what are the molecular weight of the different esters produced that is the methyl esters of the lauric acid that is having 13 carbon, so 12 into 13 plus 26 hydrogen 1 into 26 plus 2 oxygen, so 16 into 2 that is equal to 214 gram. Similarly, this is for the methyl ester of myristic acid that is equal to 242 gram and in a similar way, we can calculate it for the palmitic acid that is equal to 12 into 17 plus 1 into 34 plus 16 into 2 that is equal to 270 gram.

Now, we see what is our base. Our basis is 10 kg of the oil. So, 10 kg of the oil we are having, and it is also given that 90 percent of it is triglyceride. So, what is the amount of triglyceride present in it 10 kg into 0.9, so that is equal to 9 kg. So, what will be the moles of triglyceride in the oil 9 kg divided by 0.722 kg, so that will be the mole because the molecular weight we have calculated for this equal to 722 gram that is equal to 0.722 kg. So, that 9 divided by 0.722 that is equal to mole, so 12.465 mole of the triglyceride present in the 10 kg of bio oil that is basically 9 kg that is of 9 of kg of triglycerides.

So, moles of triglyceride converted into glycerin equal to how much in the problem it is given that 70 percent is converted. So, we will be having out of this 12.465 mole 70 percent is converted to 0.7, so that is equal to 8.7258 moles. So, these many moles of triglycerides are converted. So, what is our reaction, this is our reactions 1 triglyceride is giving 1 mole of glycerol and also 1 mole of each esters, so the glycerin produced is equal to again the same 8.7258 moles into 0.092 that is in terms of kg. So, we are converting it this moles into molecular weight. So, we are getting the kg. So, glycerin produced is equal to 0.803 kg.

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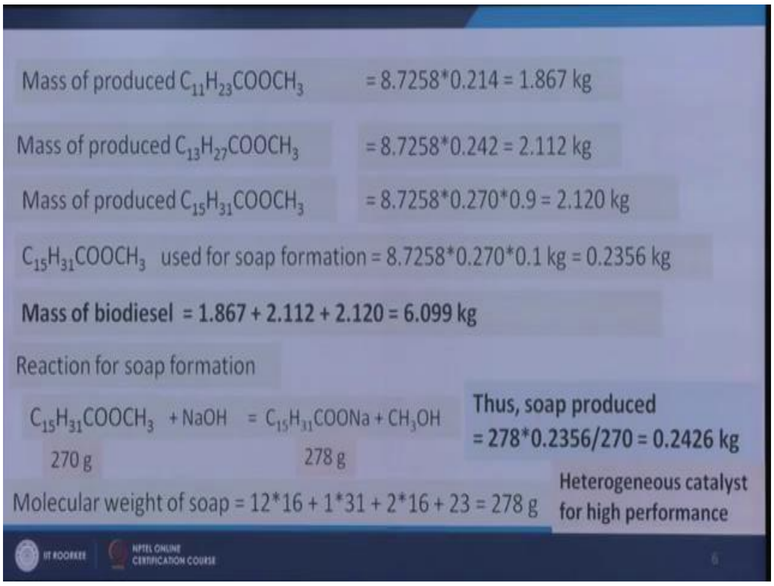

Now, what are the mass of produced the methyl esters of your lauric acid that is equal to 8.7258 into the molecular weight of this that was 214 gram, so 0.214 into this that is equal to 1.867 kg. Similarly, for mass of the produced from this, acid esters is equal to 8.7258 into 0.242 this is the molecular weight that is equal to 242 gram, so the 0.242 that is equal to 2.112 kg 2.112 kg. And the third one that is produced this equal to 2.120 kg. So, these are the different amounts of the different esters.

So, what is the now here one important thing, here we have put another 0.9, 8.7258 into 0.270 into 0. 9. Why so, because it is given in the statement 10 percent of palmitic acid is converted to soap. So, palmitic acid is converted to soap means the methyl esters of palmitic acid 100 percent is not present in it, 10 percentage is converted to soap, so that is why point 9 was used in this case. So, 2.120 kg we got the methyl esters of palmitic acid. And then what is the amount of this methyl ester of palmitic acid that has been used for the soap formation that is equal to this into 0.270 into 0.1 kg, the 10 percent of it, so 0.2356 kg. Then mass of biodiesel equal to how much mass of this plus mass of this plus mass of this, so we are getting 1.867 plus 2.112 plus 2.120 that is equal to 6.099 kg. So, this is the mass of the biodiesel and mass of the glycerin we have got.

Now, mass of soap we have to calculate now. So, these amount of methyl ester of palmitic acid is converted, so this amount of converted to soap. So, we are assuming this reaction. So, this is taking place sodium salt of this palmitic acid. So, the molecular weight of this sodium salt of palmitic acid is equal to 278 gram as we are getting molecular weight of soap is equal to 12 into 16 carbon 16 carbon and then 31 hydrogen 2 oxygen and 1 is sodium, so it is becoming 278 gram. So, thus soap produced equal to how much. So, this is our 270 gram. So, 270 gram esters is giving 278 gram of soap. So, 278 divided by 270 multiplied by 0.2356 kg, so that is our soap production, so that is coming equal to 0.2426 kgs. So, 0.2426 kg our soap production we are getting.

So, now, we have been able to calculate the production soap, production of glycerol and production of biodiesel. The last question was last part of this question was how we can improve the performance of this process. So, performance of this process can be improved if we replace the catalyst in which catalyst by some heterogeneous catalyst. So, this is the solution of the problem.

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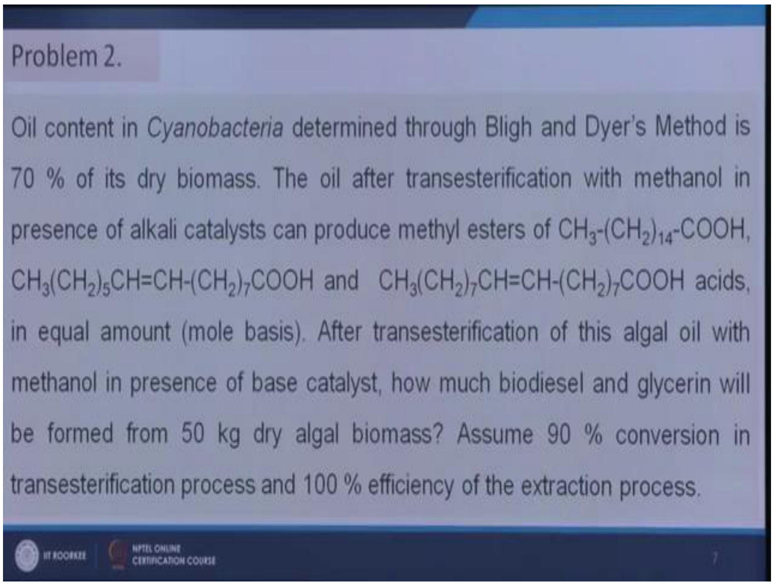

Our next problem is the statement is like this. Oil content in Cyanobacteria determined through Bligh and Dyer's method is 70 percent of its dry biomass. The oil after transesterification with methanol in presence of alkali catalysts can produce methyl esters of CH 3-CH 2 14-COOH, CH 3 CH 2 5 CH double bond CH-CH 2 7 COOH and CH 3 CH 2 7 CH double bond CH CH 2 7 COOH acids. So, these three acids methyl esters can be formed, in equal amount mole basis. After transesterification of this algal oil with methanol in presence of base catalyst, how much biodiesel and glycerin will be formed from 50 kg dry algal biomass? Assume 90 percent conversion in transesterification process and 100 percent efficiency of the extraction process. So, this has similarity between the previous one, but some difference is also there. In this case, the biomass of the dry biomass of the micro algae is given that is 50 kg. It has only 70 percent of lipid. So, 70 percent of this biomass can give us the oil because 100 percent efficiency is given, so that we will find out then other part will be the similar to the previous one.

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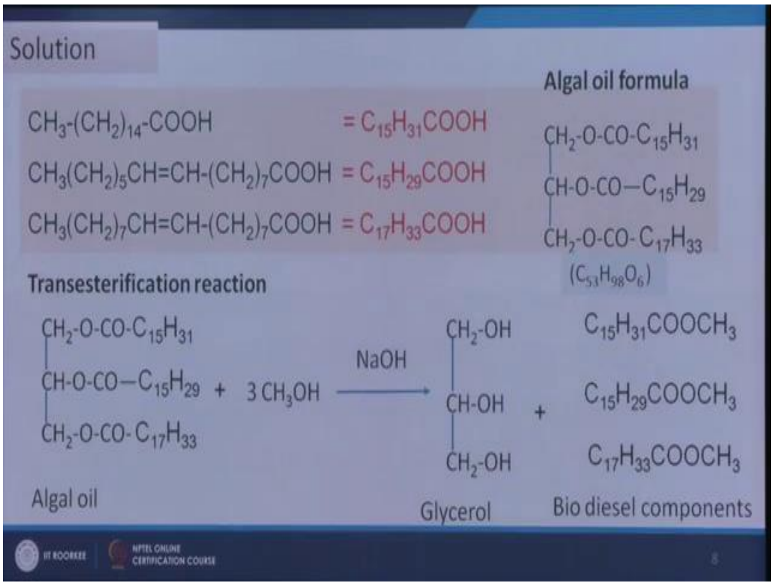

So, here we are having three different acids. So, these three different acids are C 15 C 31 COOH, C 15 H 29 COOH, and C 17 H 33 COOH. So, what will be the algal oil formula? So, these acids will be attached with the triglyceride that is the glycerol and then CH 2-O-C O-C 15 H 31, and CH -O-CO-C 15 H 29, and then CH 2-O-CO- C 17 H 33. So, this is our algal oil formula so that is C 50 3 H 98 O 6, this is the simple formula of this algal oil. Now, then what will be the reaction, this is our algal oil, it is reactive with alcohol that is methanol in presence of NAOH. So, we are getting glycerol and other three esters. So, we are getting three different esters C 15 H 31 COOCH 3, we are getting C 15 H 20 9 COOCH 3 and C 17 H 33 COOCH 3. So, these three different methyl esters we are getting.

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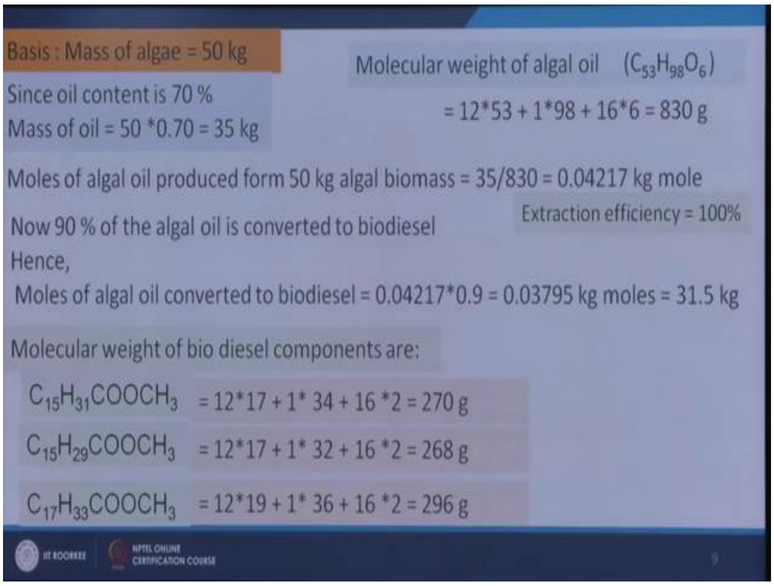

Then what is our basis 50 kg of biomass of the algae. So, 70 percent oil is there. So, what is the mass of oil, 50 into 0.7, so 35 kg, because 100 percent extraction efficiency we have got, so that is as per the statement that is why the 35 kg oil will be produced from this 50 kg of algal biomass. Then molecular weight of algal oil C 53 H 98 and O 6 in the previous slide we have seen, so 12 into 53 plus 1 into 98 plus 16 into 6, it is giving us 830 gram. So, this is the molecular weight of the algal oil. And the moles of algal oil produced from 50 kg of algal biomass that is equal to 35 kg oil divided by 830 gram that is equal to 0.04217 kg mole - 35 kg, and this is our 830 gram. So, we are getting this our kg mole.

Now, 90 percent of the algal oil is converted to biodiesel, it is given that 90 percent of the algal oil is converted to biodiesel. So, most of algal oil, which we are having these moles kg moles, so that will be converted to biodiesel 90 percent of it 0.9 of it that is we are getting 0.03795 kg moles that is equal 31.5 kg. How we are getting 31.5 kg, we have to multiply it with 830. So, 31.5 kg of this algal oil converted so molecular weight of biodiesel components.

Now, we will see the molecular weight of biodiesel components we have three components here. So, methyl esters of these three acids actually, so we are getting 17 carbon 15, 16, 17, so 17 into 12 plus 1 into 34 hydrogen and then 16 into 2, 2 oxygen, so it is 270 gram. Similarly, for this, we are getting 268 gram; and for this we are getting

296 gram. So, these are the molecular weight of these biodiesel components. Then the same the reactions 1 mole algal oil gives 1 mole glycerol and 1 mole of the esters each.

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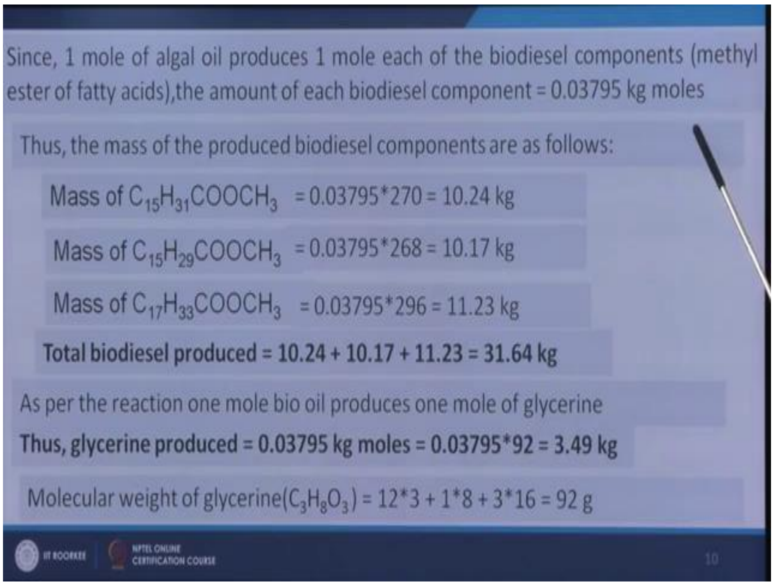

So, since one mole of algal oil produces 1 mole each of the biodiesel components methyl esters of the acids, so the amount of each biodiesel component will be the similar the 0.035795 kg moles, because this is the conversion of algal oil. These moles of algal oil is converted to biodiesel, the same moles of glycerol and that each component of the biodiesel will be produced. Thus the mass of the produced biodiesel components are, so we have to multiply this number of moles with the molecular weight. So, we are getting this into 270 that is 10.24 kg.

For the second one, we are getting this into 268 that is 10.17 kg. In the third one, we are getting 0.03795 into 296 molecular weight, so 11.23 kg. So, what will be our total biodiesel, so this plus this plus this will be our total biodiesel. So, total biodiesel production this plus this that is 31.64 kg. So, now as per the reaction 1 mole bio oil produces 1 mole of glycerin also. So, glycerin production will be similar this into molecular rate of this, so this equal to 92 psi that is equal to 3.49 kg.

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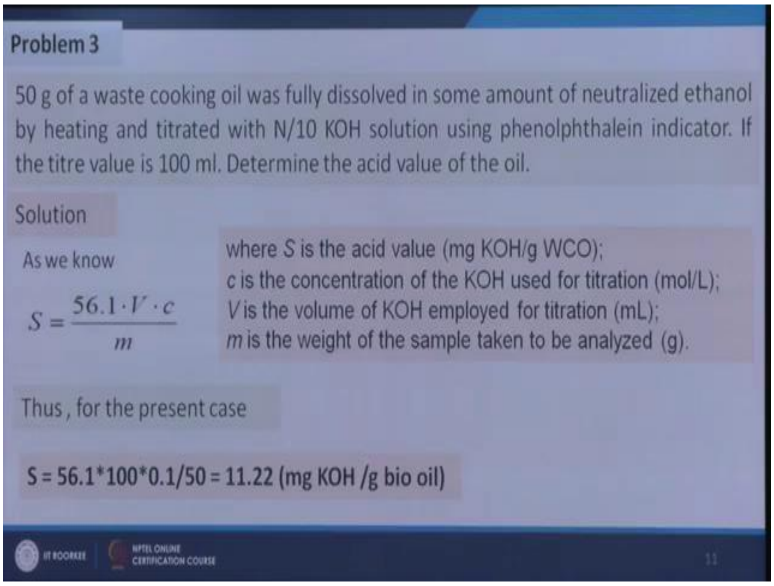

Now, we are coming to our next problem. In this problem, the statement is 50 gram of a waste cooking oil was fully dissolved in some amount of neutralized ethanol by heating and titrated with N by 10 KOH solution using phenolphthalein indicator. If the titre value is 100 ml, determine the acid value of the oil. So, we have to determine the acid value of the oil. For that we have already discussed in the previous module that acid value can be determined as per this formula that is 56.1 into V into c by m. What is V and c and m? V is the volume of the KOH solution added in ml, and C is the concentration of KOH used in mole per liter, and m is the weight of the sample taken to be analyzed in gram. So, this is the formula to determine the acid value.

Now, as we also discussed in the previous module that is neutralized ethanol is made through specific protocol. So, we are not going there. So, we have now we have this formula and the information are given. We have 50 gram of waste cooking oil. So, m value is our 50. So, what is our V? V it is 100 ml, so we are getting 100 ml as V. And then what is our c, c is N by 10; that means, in case of k O H normality and monorality are same KOH so that is mole per liter this will be one by 10, so 0.1. So, 0.1 into 100 into 56.1 divided by 50 that is equal to 11.22 m g KOH per gram of bio oil. So, this is our acid value of this bio oil.

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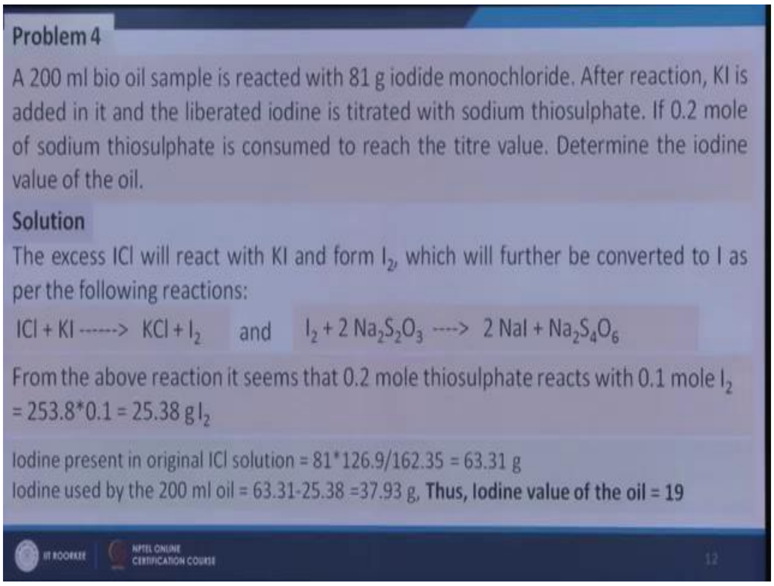

This is the next problem. The statement of this problem is that a 200 ml bio oil sample is reacted with 81 gram iodine monochloride. After reaction, KI is added in it and the liberated iodine is titrated with sodium thiosulphate. If 0.2 mole of sodium thiosulphate is consumed to reach the titre value, titrate point titration point, so determine the iodine value of the oil. So, we have to determine the iodine value of the oil on the basis of this information. So, what is the definition of iodine value of oil? Iodine value is the amount of iodine in gram used by 100 ml of oil that is the iodine value. So, how much iodine in gram is used by the oil is our iodine value and iodine value indicates the number of unsaturation presence in it, the degree of unsaturation present in the oil. So, in this problem, what happens in the oil sample we are adding ICL iodine monochloride.

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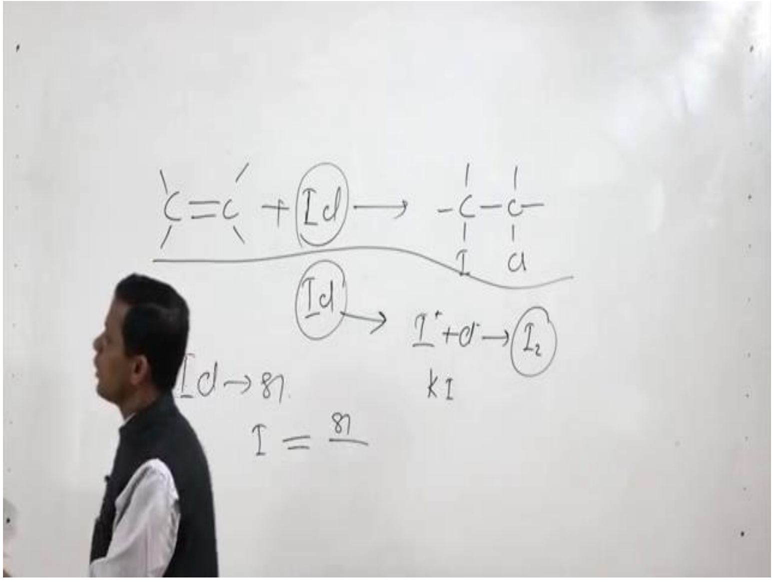

So, iodine monochloride will be reacting with a double bond, so which is having their C, so where I Cl, it will give us Cl. So, I Cl which we are adding part of it will be used for this reaction rest of this is available in the solution, rest of I Cl will be available in the solution, so that I Cl will react with KI when we will be adding some additional K I into the solution after the reaction. So, that KI will convert this iodide present in the solution to iodine iodide to iodine. So, I C l which is present in this solution that will be in this form and it will give us iodine in presence of KI, in presence of KI, it will be giving us iodine. So, this iodine will further react with sodium thiocyanate, by this reactions and it will convert to tetra thiocyanates, sodium tetra thiocyanate.

So, when this reaction takes place and all the iodine will be consumed that can be traced by adding some indicator. So, starch indicator is used. So, at the end point how much Na 2 S 2 O 3 is used to reach the end point, and how much Na 2 S 2 O 3 is used that can be calculated. And as per the statement, that is 0.2 mole. Here we see in this reaction two moles of this thiosulphate is reacting with one mole of iodine. So, from the above reaction, it seems that 0.2 mole of thiosulphates reacts with 0.1 mole of iodine, and 0.1 mole of iodine is equal to how much 253.8 into 0.1 that is equal to 25.38 gram of iodine. So, this iodine is available after this reaction, after this reaction, this is available is equal to 25.38 gram.

And now how much initial was available, what was the initial that is 81 gram iodine monochloride. So, 81 gram iodine monochloride was 81 gram. So, what is the iodine in it that will be 81 divided by this molecular weight 126.9 divided by 169.35, so that is equal to 63.21 gram. So, 63.21 gram these are in terms of iodide this is in terms of iodide, so this minus 25.38. So, 63.31 minus 25.38 that is equal to 27.93 gram, so this is our iodide present in it. So, iodine used by this 200 ml oil. So, iodine used by this 200 ml oil is equal to 37. 93gram. So, thus iodine value of this oil is equal to this divided by 2 that is around 19, so up to this in this module.

Thank you for your patience.