Technologies for Clean and Renewable Energy Production
Prof. Prasenjit Mondal
Department of Chemical Engineering
Indian Institute of Technology – Roorkee

Lecture - 40
Tutorial

Hi friends, I welcome you all to the last class of this course, technologies for clean and renewable energy production. Now, we will have a tutorial session which is based on the last Four classes, and in this class, we will solve some numerical problems.

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Problem 1.

Bio oil extracted from an oil seed sample has 90 % triglycerides containing three long chains, which can produce methyl esters of lauric acid ($CH_3(CH_2)_{10}COOH$), myristic acid ($CH_3(CH_2)_{12}COOH$) and palmitic acid ($CH_3(CH_2)_{14}COOH$) in equal molar ratio during transesterification using methanol and NaOH catalyst. Calculate the amount of biodiesel produced by the transesterification of 10 kg of bio-oil. Assume efficiency of the conversion is 70 % ; and 10 % of plamitic acid is converted to soap. How much glycerol will be produced and how much soap will be produced? How can we improve the efficiency of the transesterification?

Our first problem the statement is the bio oil extracted from an oil seed sample has 90% 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 NaOH catalyst. Calculate the amount of biodiesel produced by the transesterification of 10 kg of bio oil. Assume efficiency of the conversion is 70% and 10% of palmitic acid is converted to soap.

How much glycerol will be produced and how much soap will be produced. How can we improve the efficiency of the transesterification? So this is the problem statement. We are asked to calculate how much glycerol will be produced and how much soap will be produced and how the efficiency can be improved. It is given that after the transesterification, the methyl esters of lauric acid, myristic acid, and palmitic acid are produced.

It is also given that 90% triglycerides are converted to biodiesel or the methyl esters of these 3 acids in equal mole, so this is given.

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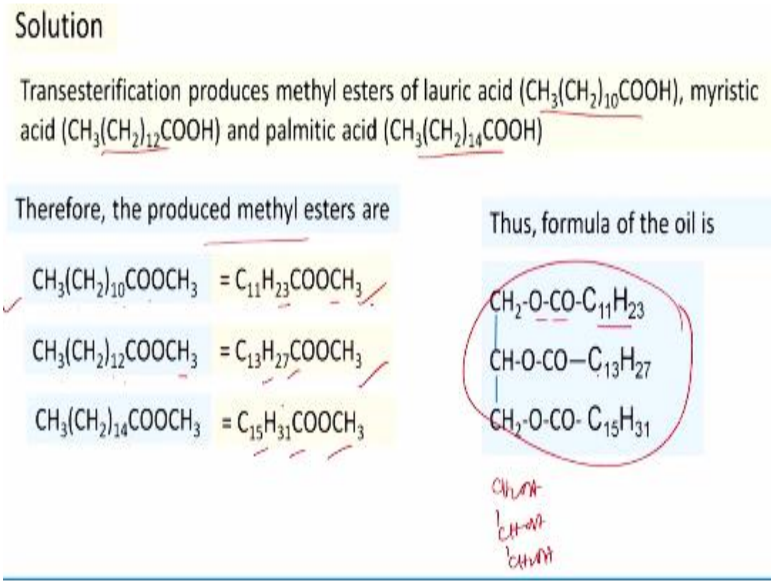

So at first, we have to get what is the molecular formula of the triglyceride, and as it is given that methyl esters of these 3 acids lauric, myristic, and palmitic acid has formed, so the produced methyl esters are given here. So $CH_3(CH_2)_{10}COOH$, this OH will be replaced by CH_3O. So $CH_3(CH_2)_{10}COOCH_3$, then for this acid C_2, this is equal to we are getting $C_{11}H_{23}COOCH_3$.

For the second myristic acid, our methyl esters is $CH(CH_2)_{12}COOCH_3$ that is equal to $C_{13}H_{27}COOCH_3$. Similarly for palmitic acid, the methyl esters usually produced there is equal to $CH_3(CH_2)_{14}COOCH_3$ that is $C_{15}H_{31}COOCH_3$. Now what is the formula of the triglyceride or the oil that is one is you glycerol $CH_2OHCH_2OHCH_2OH$, then H is replaced by this, so $C_{11}H_{23}COO$ and CH_3OH will be there and CH_2 will be there.

That means you have CH_2OH, CHOH and CH_2OH, this will form and this will react with CH_3O and it is giving us $C_{11}H_{23}COOCH_3$, OCH_3 is coming from the methanol, which is used in case of the reaction which you have discussed in previous chapter. So this is the formula of the oil or triglyceride we can get, and these are 3 methyl esters which are produced during the process.

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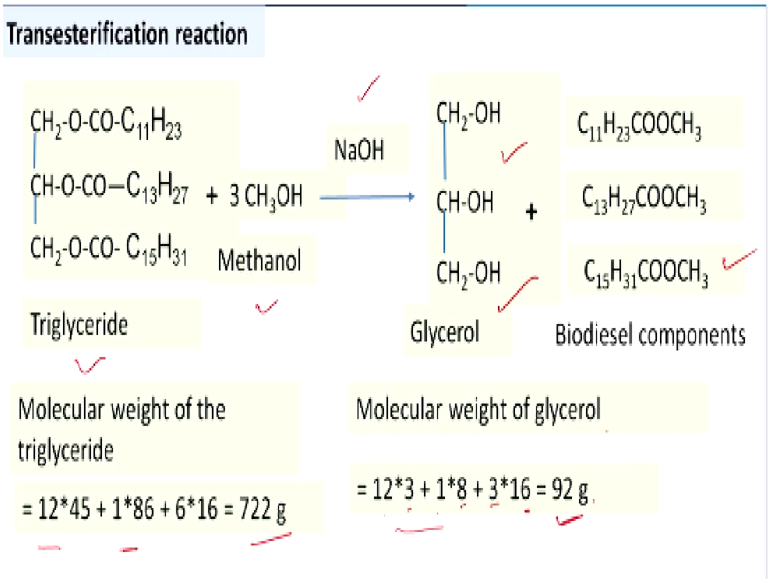

So this is the scheme a triglyceride reacts with methanol in presence of NaOH and then it gives glycerol + 3 methyl esters of 3 different acids. So now the molecular weight of the triglyceride which is given here that is equal to 12 x 45 + 45C, then 86 a hydrogen, so 1 x 86 + 6 oxygen, so 16 x 6, we are getting 722 gram. This is the molecular weight of triglyceride. Then molecular weight of glycerol this is, so that is equal to 92, so 3 carbon x 12, 8 hydrogen x 1 + 3 oxygen x 16, so it is becoming 92 gram.

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Molecular weight of $C_{11}H_{23}COOCH_3$ = 12*13 + 1*26 + 16*2 = 214 g

Molecular weight of $C_{13}H_{27}COOCH_3$ = 12*15 + 1*30 + 16*2 = 242 g

Molecular weight of $C_{15}H_{31}COOCH_3$ = 12*17 + 1*34 + 16*2 = 270 g

Basis : 10 kg bio oil

Triglyceride = 10 *0.9 = 9 kg

Moles of triglyceride in the oil = 9/0.722 mole= 12.465 mole

Moles of triglyceride converted into glycerine = 12.465 * 0.7 = 8.7258 moles

Glycerine produced = 8.7258*0.092 kg = 0.803 kg

Similarly, we can get the molecular weight of this methyl esters of lauric acid and this is myristic acid and methyl ester of palmitic acid. Then the molecular rate we are getting 12 x 13, here are 15, 13, 11. So here 12 x 13, so 13 carbon x 12 + 23 +3, 26 hydrogen x 1 + 2 x 16, 2 oxygen x 16, so 214 gram and here we are getting 12 x 15, so 15 carbon x 12 + 30 hydrogen x 1 + 2 oxygen x 16, so 242 gram.

Similarly for these methyl esters that is palmitic acid methyl esters, so 12 x 17 + 1 x 34 + 16 x 2, so 270 gram. So these are the molecular weight of these methyl esters of different fatty acids. So now our basis is 10 kg of bio oil and then triglyceride is 90%, So 0.99 kg. So moles of triglycerides in the oil is 9/we have molecular weight is equal to 722 gram, so 0.722, we have to divide that mole, so that is 12.465 moles is available in 9 kg because 1 kilo mole is equal to this 0.722 kg.

So moles of triglyceride converted into glycerin that 70% is converted. So it is given 70% is converted. So we have to multiply it by 0.7, so 8.7258 moles we are getting. So glycerin produced will be this much moles multiplied by the molecular weight of glycerin, that is equal to 92 gram, so 0.92 kg, so 0.803 kg. This much of glycerin is produced. The first part is determined.

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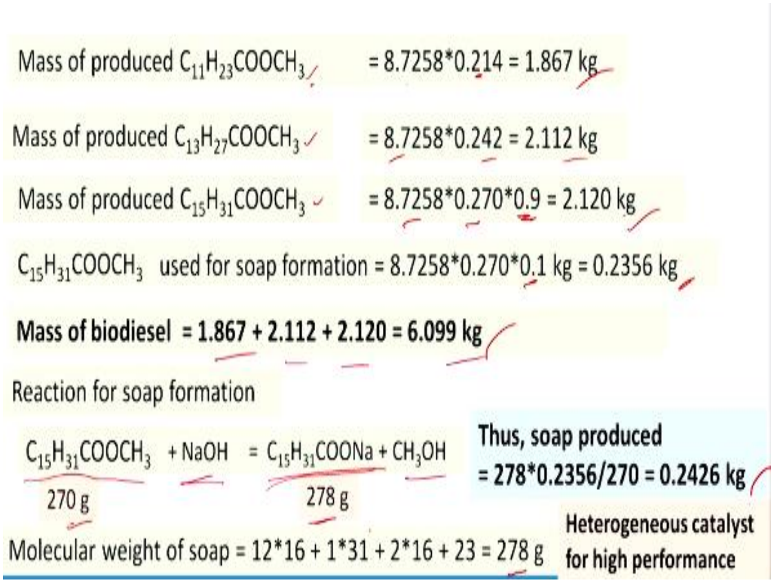

Now mass of produced $C_{11}H_{23}COOCH_3$ is equal to how much then, we have the reaction, 1 mol glycerol produces 1 mol of each of these methyl esters of the fatty acids, so how many moles we are getting here 8.7258, so that will also be same number of moles will be produced for this, moles of these methyl esters of these acids will also form. So this x the molecular weight of this 214 grams, so 0.214, that is equal to 1.867 kg.

Similarly for this case, this x this equal to 2.112 kg, and for this case this x this is equal to methyl esters of palmitic acid not 100% converted into this ester, some salt is also formed that is 10%, so 90% of this one, so 0.9 will be there, so this 2.120 kg is for methyl ester formation, remaining 10% will be for soap formation. So mass of biodiesel will be how much then, this + this + this, so this + this + this, 6.099 kg.

Then reaction for soap formation we have, this is the ester that will react with NaOH, excess NaOH and it gives a sodium salt of this fatty acids and CH_3OH. So this sodium salt of this fatty acids molecular weight 278 whereas this we have 270 gram. So molecular weight of soap we can determine 278, so what will be the soap produced. Soap produced will be 278/270 x how much of this ester is formed, so that is 0.2356, so that is equal to 0.2426 kg.

So now we are able to determine how much soap will form, how much biodiesel will form, and how much glycerol will form after the transesterification of this oil. So how we can improve the efficiency, we can use the heterogeneous catalyst. Here we have used the homogeneous catalyst, so soap formation is there, but if we use heterogeneous catalyst, soap formation will not be there and we will get the improved performance of the process.

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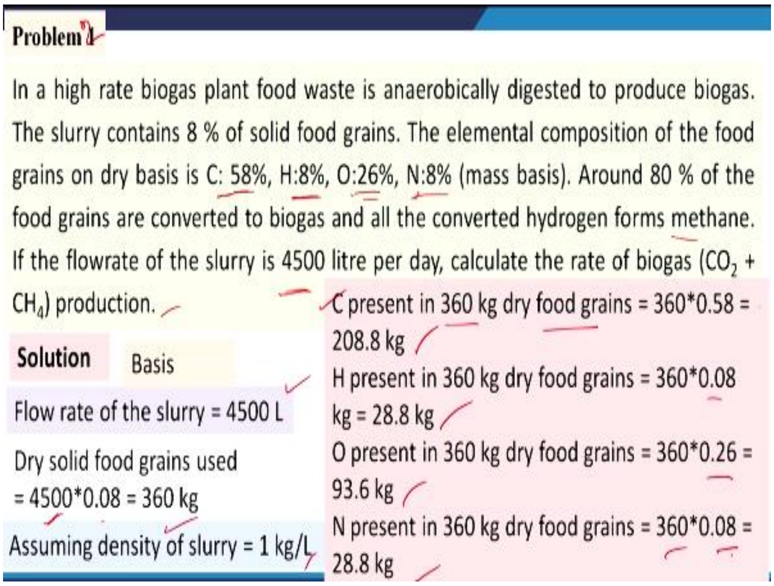

Then next problem number 2. In a high rate biogas plant food waste is anaerobically digested to produce biogas. The slurry contents 8% of solid food grains. The elemental composition of the food grains on dry basis its carbon 58%, hydrogen 8%, oxygen 26%, percent, nitrogen 8% on mass basis. Around 80% of the food grains are converted to biogas and all the converted hydrogen forms methane.

If the flow rate of the slurry is 4500 liter per day, calculate the rate of biogas CO_2 + CH_4 production. This is the problem statement. We have to calculate the biogas productions that is CO_2 and CH_4 and the slurry were using is given for 4500 liter per day and how much organic solid is available that is also 8% food grains and composition is also given carbon, hydrogen, oxygen, nitrogen. So by simple mass balance, we can solve the problem.

So what is our basis flow rate of the slurry is 4500 litre it is given. If we assume the density as 1, so then 4500 kg will be the mass of this slurry, so 8% is solid, so 0.08 x 4500 that is 360 kg is our organic load in it, organic solids on it. Then the carbon percent, hydrogen, oxygen, nitrogen is given. So how many carbon gram or kg of carbon is present that we can get, that is carbon present in 360 kg dry food grains = 360 x 0.58, so that is equal to 208.8 kg.

So hydrogen is 360 x 0.08 that is equal to 28.8 kg, and oxygen is 360 x 0.26, that is 26%, so 93.6 kg, similarly for nitrogen 360 x 0.08, so 28.8 kg. So these are the different elements present in these organic food. Now it is given that 80% of food grains are converted to biogas, so 80% of these components will also be converted to different oxide forms.

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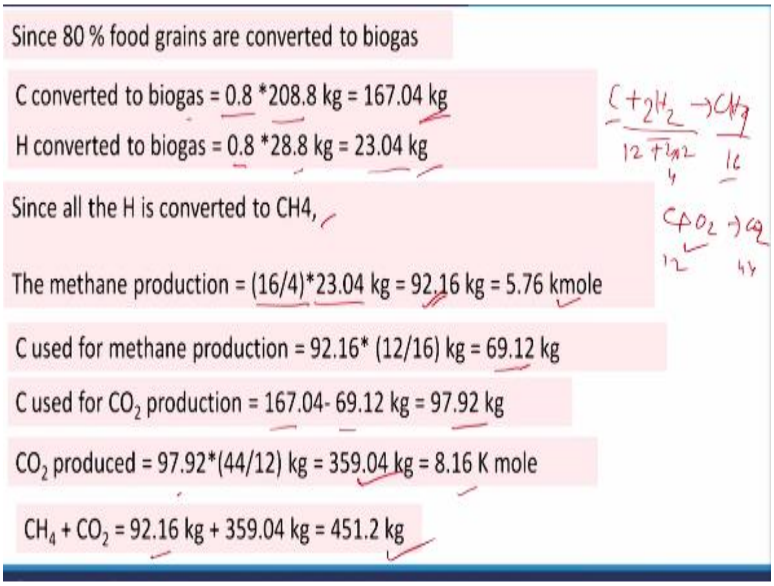

So carbon will be converted to biogas that is 0.8 x 208.8 = 167.04 kg. Hydrogen will be converted 80% of total that is 23.04. Since all the hydrogen is converted to CH_4, it is given the hydrogen is completely converted to CH_4, so methane produced will be how much. So CH_4, C + H, CH_4 it is giving, so $2H_2$, 1 mol it is giving one carbon reacts with $2H_2$ and gives CH_4.

So this is your 12 + 2 x 2 and this is equal to 16, so the this 16 from 4 gram, we are getting 16 gram methane, 4 gram of hydrogen, we are getting 16 gram. So now we are using this hydrogen 23.04 kg, so this x 16/4 that will be the methane production, so that is equal to 92.16 kg or 5.76 kilo mole. Now carbon used for methane production, so carbon converted is your this much and then this much kg carbon used for methane production for this reaction.

So carbon + O_2, CO_2 this reaction will also take place, so rest of the carbon may be used for this. So total is your 167.04 and minus this that is equal to 97.92 kg is used for this reaction, $C+O_2 = CO_2$. What would be the CO_2 produced, CO_2 produced will be this much carbon you know 44 and this is 12, so 44/12 x 97.92, so it is giving 359.04 kg that is equal to 8.16 kilo mole.

So $CH_4 + CO_2$ = how much now, now we are getting 92.16 kg this is methane produced + CO_2 produced. So CO_2 produced is 359.04 kg, so total 451.2 kg for biogas is produced.

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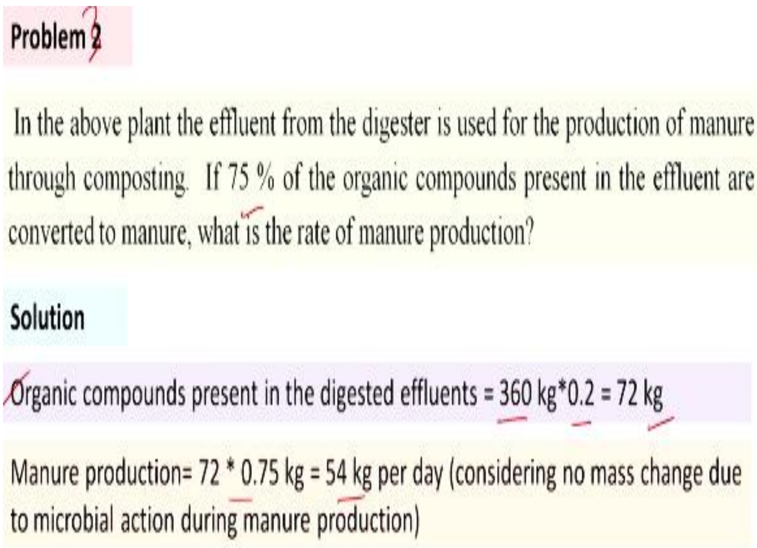

Now problem number 3. In the above plant, the effluent from the digester is used for the production of manure through composting. If 75% of the organic compounds present in the effluent are converted to manure, what is the rate of manure production. So what is the sludge we are getting that is converted to manure 75% organic compounds present in the effluent.

So organic compounds present in the effluent is equal to how much, 80% is converted to biogas, so rest 20% will be available. So 360 x 0.2 that is 72 kg. Out of this, 75% is converted to manure, so what will be this 72 x 0.75, so 54 kg per day manure will be produced.

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Problem 3

A 60 HP Energy Efficient Motor is operating a 75% load. At this load, efficiency of the motor is 87% and the power factor is 0.83. A standard motor with same load shows an efficiency of 80 % and power factor of 0.8. If the price of one unit of electricity is Rs 3.10. Calculate the annual saving in expenditure for energy. Assume 20 h consumption per day for 300 days in a year. Assume VA demand charge as Rs. 175/- per kVA per month.

Then problem 4. A 60 HP energy efficient motor is operating at 70% load. At this load, efficiency of the motor is 87% and the power factor is 0.83. A standard motor with same load shows an efficiency of 80% and power factor of 0.8. If the price of one unit of electricity is rupees 3.10, calculate the annual saving in expenditure for energy. Assume 20 hour consumption per day for 300 days in a year.

Assume VA demand charge as rupees 175 per kVA per month. So similar type of problems we have discussed in energy conservation chapters where we have calculated the time required to recover the amount and payback period, but now we have to calculate only the annual saving in expenditure.

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Solution:

Rating of energy efficient AC motor = 60 x 0.75 = 45 kW

Input power to motor = 45 x 0.75 / 0.87 = 38.79 kW

kVA demand = 38.79 / 0.83 = 46.73 kVA

kVA charges/year = 46.73 x 175 x 12 = Rs. 98,133/-

Energy (kWh) charges/year = 38.79 x 3.10 x 20 x 300

= Rs. 7,21,494/-

Total (Energy + Demand) charges/year = 7,21,494 + 98,133

= Rs. 8,19,627/-

So rating of the energy efficient AC motor is 60 x 0.75, this 75 because the conversion of HP to watt, so that is in kilowatt 750 watt equal to 1 horsepower we are assuming. So 60 x 0.75 = 45 kilowatt. So input power to motor 45 x 0.75/0.87, this is energy efficient motor, so we are getting 38.79 kilowatt. The kVA demand 38.79/0.83 because the power factor is 0.83 and it is given here.

So this value is coming 46.73 kilo kVA, kilovolt ampere. So kVA charges per year is equal to this much x 175 x 12 that is 98,133. Energy charge = 38.79 x 3.10 x 20 x 300, so that is equal to rupees 7, 21,494. So energy demand + energy cost, we are getting this + this one = 8, 19,627 rupees.

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Rating of standard AC motor = 60 x 0.75= 45 kW

Input power to motor = 45 x 0.75 / 0.8 = 42.19 kW

kVA demand = 42.19/0.8 = 52.73 kVA

kVA charges/year = 52.73 x 175 x 12 = Rs. 110742/-

Energy (kWh) charges/year = 42.19 x 3.10 x 20 x 300

= Rs. 784734/-

Total (Energy + Demand) charges/year = 784734 + 110742

= Rs. 895476/-

Annual Saving = 895476-819627= 75849

Rating of standard AC motor is 60 x 0.75, again that is equal to 45 kilowatt. Then power input divided by 0.8, so 42.19 kilowatt. So kVA demand is 42.19/0.8, 52.73 kVA. So kVA charge, this x 175 x 12, rupees 1, 10,742. Energy charge per year is equal to this one, 42.19 x 3.10 x 20 x 300, so 7, 84,734 rupees. So total 8, 95,476. So here we are getting the annual saving is 8, 95,476 - 8, 19,627, so rupees 75,849.

So up to this in this class, and I hope you will enjoy the course and best of luck to those who will take part in the examination. Thank you very much for selecting this course and for your patience.