Waste to energy conversion
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Lecture - 17
Tutorials on Pyrolysis

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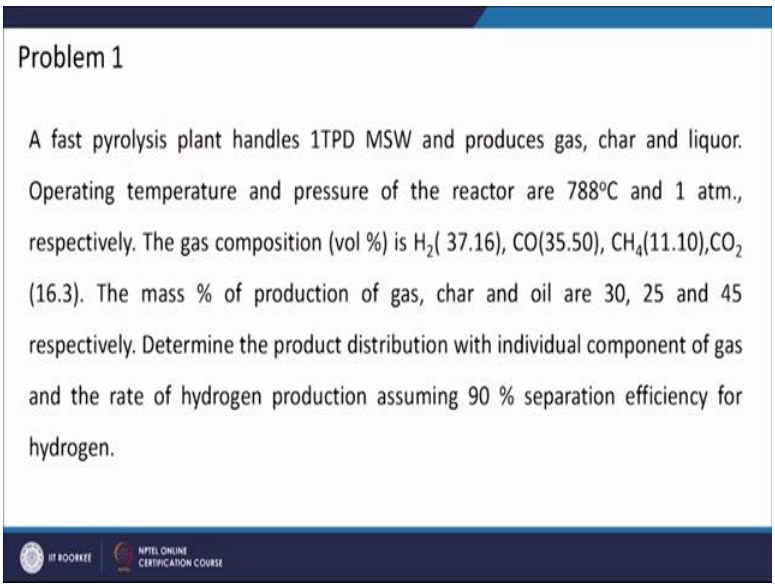

Morning everyone. Now, we will discuss on the module tutorial on pyrolysis. In the last module on pyrolysis we have discussed on the fundamentals of pyrolysis its mechanism different steps reactors of pyrolysis etcetera and now will be solving some numerical problems. Now, let us come to the first problem. So, the statement of the first problem is a fast pyrolysis plant handles one tonnes per day MSW and produces gas char and liquor operating temperature and pressure of reactor are 788 degree centigrade and one atmospheric pressure respectively.

The gas composition is 37.16 H 2, CO 35.50, CH 4 11.10, CO 16.3 percentage volume basis and mass percentage of product production of gas char and oil are 30, 25, and 45 percent respectively. Determine the product distribution with individual component of gas and the rate of hydrogen production assuming 90 percent separation efficiency for hydrogen. So, this is the problem statement we have to solve it and to solve this we will take one basis. So, on the basis of this we have got the conversion of gas char and liquid. So, we will calculate it the how much char is produced how much gas is produced and

how much liquid is produced the first part is over that is the distribution on mass basis is over. Then we have to also calculate the individual component of gas that may be mass basis may be in volume basis on may be in mole basis as the temperature is different from the normal temperature or STP or NTP. So, we need to calculate the compositions in volume.

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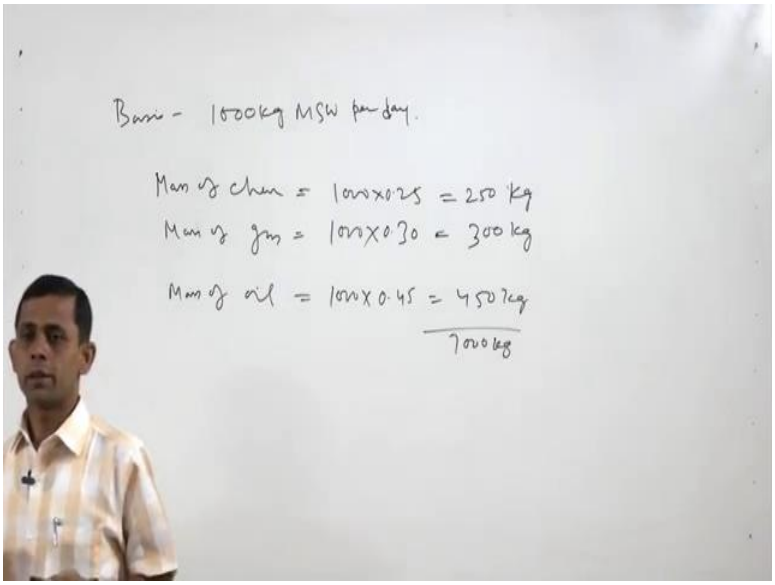

So, let us take the basis of 1000 kg MSW per day. So, this is our, that is your 1 ton per day, so 1000 kg per day MSW per days. So, what will be the mass of char it is given char is equal to 25 percent mass of gas and mass of oil. So, char is 25 percent, so into 0.25250 gram kg this will be this kg and gas is equal to 1000 into 0.30 that is equal to 300 kg and oil is equal to 1000 into 0.45, so that is equal to coming 450 kg. So, total is 1000 kg. So, mass distribution of different product we have got. Second, we have to individual component. So, another data is given that is the composition of the gas. So, composition of the gas that is given, so and it is also given in volume percentage. Now, what will be the average molecular weight of the gas that we need to calculate?

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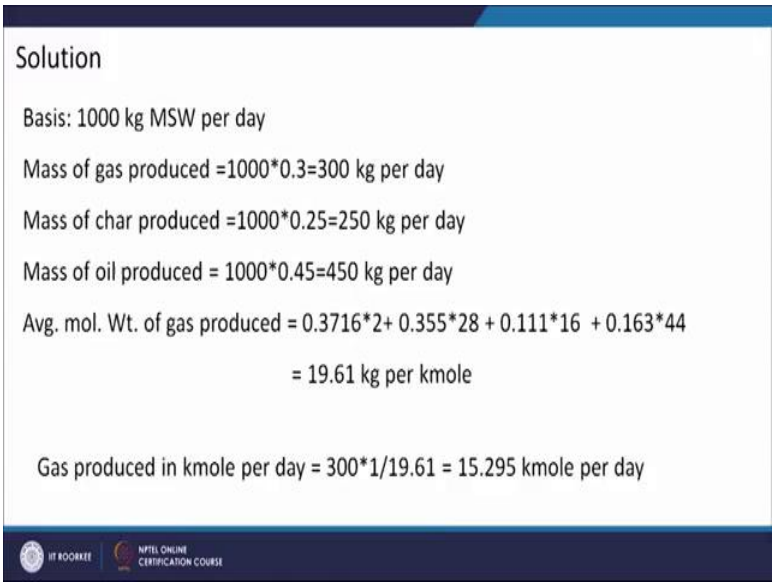

So, average molecular weight 37.16 percent hydrogen. So, that is the volume percentage. So, mole percentage will also be the similar.

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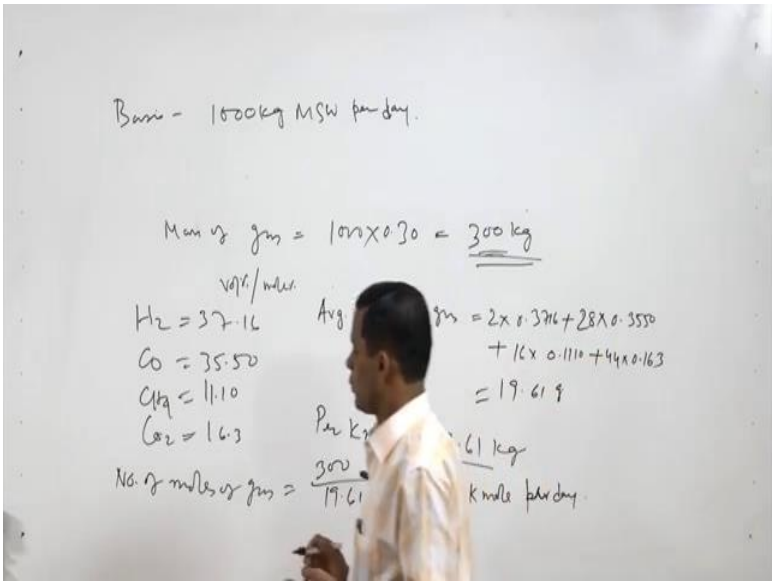

So, volume percentage of hydrogen, so hydrogen is equal to 37.16, and CO is equal to 35.50, CH 4 is equal to 11.10, CO 2 is equal to 16.3. So, these are the on volume percent or mole percent. So, what will be the average molecular weight of gas? That is equal to 2 into 0.3716 plus 28 into 0.3550 plus 16 into 0.1110 plus 44 into 0.163. So, this is the average molecular weight, so that we are getting 19.61 kg, 19.61 kg, this will be in gram.

So, 1 kilo mole will be this kg. So, this will be in gram, so per kilo mole, the mass will be 19.61 kg. Now, we have gas is equal to 300 kg.

So, how many moles are present we can calculate? So, number of moles of gas is equal to this 300 kg divided by 19.61 kg that is equal to 15.295 kilo mole. So, this is per day, this is per day. So, this much of gas is produced. Now, on mole basis, we have got how many moles of gas is produced. Now we will go for individual composition, now we will see how much hydrogen is produced, how many mole of hydrogen will be produced.

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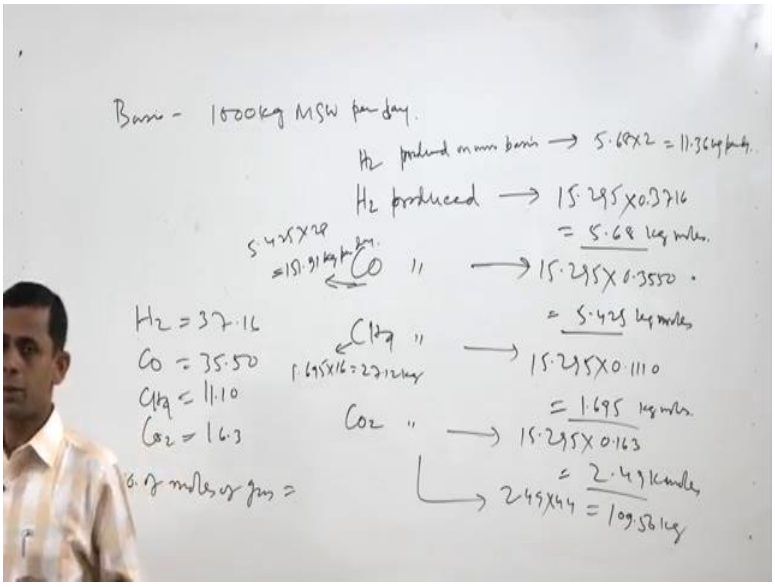

So, hydrogen produced per day that is equal to how much we are having 37.16 percent, and we have got 15.295 moles kilo moles are produced per day, out of this 37.16 percentage of hydrogen. So, our hydrogen produced equal to 15.295 into 0.3716, there is equal to 5.68 kg mole that is equal to 5.68 kg mole, so that is individual component for hydrogen. Similarly, for CO, how much CO is produced CO will be produced is equal to 15.295 into 0.3550 kilo moles, so that is equal to we are getting that is equal to 5.425 kg mole.

Next, we see how much CH 4 is produced, how much methane will be produced. So, CH 4 produced will be 15.295 into 0.1110 and this is equal to this coming 1.695 kg moles. And next is CO 2, so CO 2 will be 15.295 into 0.163, 0.163 that is equal to we are getting that 2.49 kilo moles. So, now the product distribution on mole basis how many moles are produced per day we are getting.

Now, if we want to calculate the mass basis, how much of hydrogen will be getting per day, how much of CO and CO 2, CH 4 etcetera then we will multiply it with the molecular mass of it. So, 5.68 this will be multiplied by 5.68 kg mole we are getting. So, this will be multiplied by 2 for hydrogen, hydrogen produced on mass basis this, hydrogen produced on mass basis is equal to 5.68 into 2, we are getting that is equal to 11.36 kg per day. Similarly, for carbon monoxide, we will be multiplying this with the molecular weight of CO, so that is equal to 28 into five point. So, CO 2 one mass basis will be 5.425 into 28, so that is equal to 151.91 kg per day, this is from mass basis. Then what will be the CH 4. So, CH 4 we have got here 1.16, so that will be 1.695 kilo moles into 16, so that is equal to 27.12 kg and CO 2 will be how much 2.49, so that will be mass basis 2.49 into 44. So, then it is coming as 109.56 kg. So, now on the mass basis we are getting the individual composition of the gas molecules.

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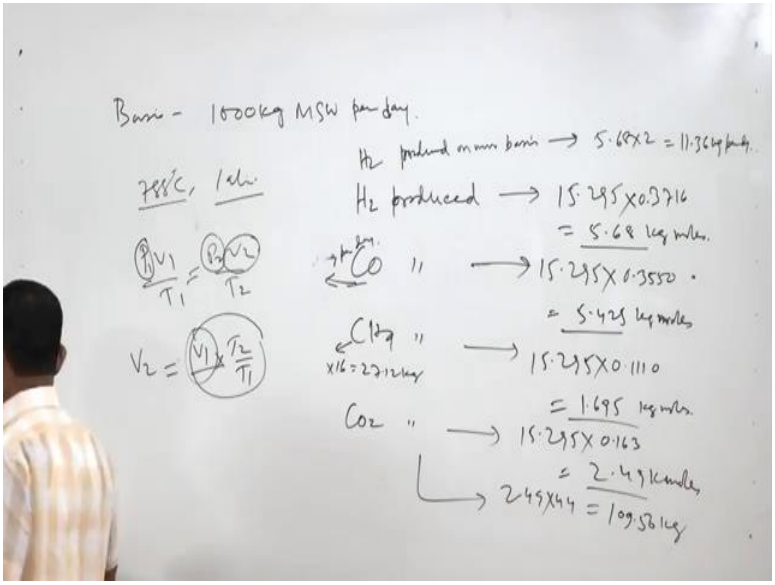

Then we have to convert it into volume basis, because the temperature is higher with respect to STP and NTP. So, we need to get the actual volume at 788 degree centigrade and 1 atmospheric pressure. So, as you know 1 molar any gas at NTP will give us 22.4 litre volume. So, we know the number of moles, we will multiply these moles with the 22.4 litre, we convert it kilo moles into moles and we will multiply it into 22.4, so that much of litre will be produced at NTP. But we need to convert it at 788 degree centigrade and 1 atmospheric pressure. For these conversions, we know that P 1 V 1 by T 1 equal to P 2 V 2 by T 2. So, here P 1 atmospheric pressure P 2 equal to 1. So, both

are 1 atmospheric pressure. So, we need to calculate V 2. So, V 2 is equal to V 1 into T 2 by T 1 given into T 2 by T 1. So, this V 1 will get by multiplying 22.2 into this after converting into litre, then we divide it by multiplied by T 2 by T 1.

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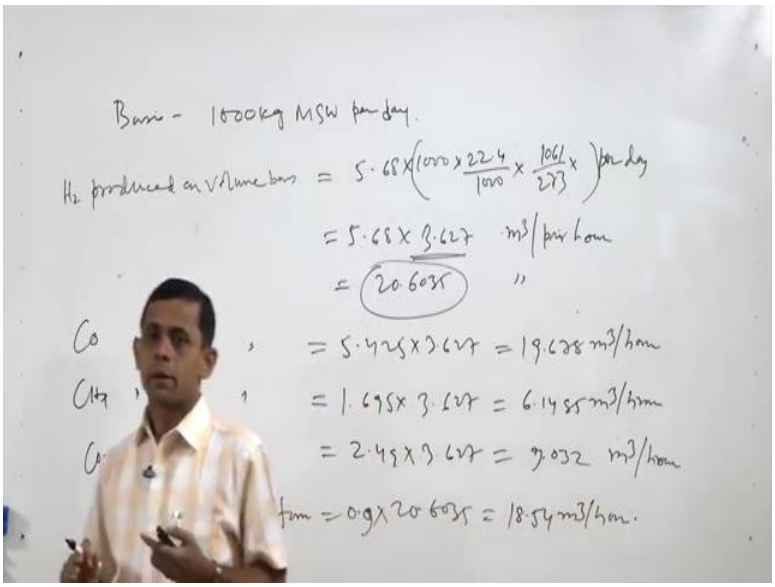

Now, the hydrogen produced on volume basis that is equal to 5.68 kilo moles 5.68 into 1000, this is mole is equal to mole, multiply it into 22.4. So, this is litre then multiply it. So, divide it by 1000, so that will be meter cube then this P 1 V 1 by T 1 that ratio. So, the V T equal to T 2 by T 1, so that is equal to 788 plus 273, so that is equal to 1061. So, this 1061 divided by 273, but this is produced per day, this is produced per day this is per day, this is per day.

Now, if you want to converted into per hour then we will divide it by 24, we will divide it by 24. So, this is coming equal to 5.68 into this of 3.627 meter cube per hour that will be the meter cube per hour. So, this is equal to we are getting is equal to 20.603 meter cube per hour, this is for hydrogen. Similarly, for CO produced on volume basis that is equal to the volume of CO that 5.425 we got, so 5.425 kilo moles into this, this first portion will be the same for all, this potion will be the same that means 3.627, so that is equal to 19.678 meter cube per hour.

Then let us see methane formation CH 4 produced on volume basis that is equal to the moles of CH 4 we had is equal to 1.695 into 3.627 this factor, so that is equal to 6.1485 meter cube per hour. And the remaining is CO 2, so CO 2 production on volume basis.

So, how many moles of CO 2 we had that was 2.49 kilo mole 2.49 into 3.627 that is equal to we are getting 9.032. So, 9.032 meter cube per hour. So, this is the production of different gas components individual gas components.

Another question was that if 90 separation efficiency is there for the separation of hydrogen from the gas what will be the hydrogen production rate. So, hydrogen production rate we have got here that is equal to 20.6035 meter cube per hour. So, 90 percent if you can separate, so hydrogen production that is in pure form 0.9 into 20.6035 that is equal to 18.54, 18.54 meter cube per hour. So, now total problem is solved. So, now we will move to the next problem.

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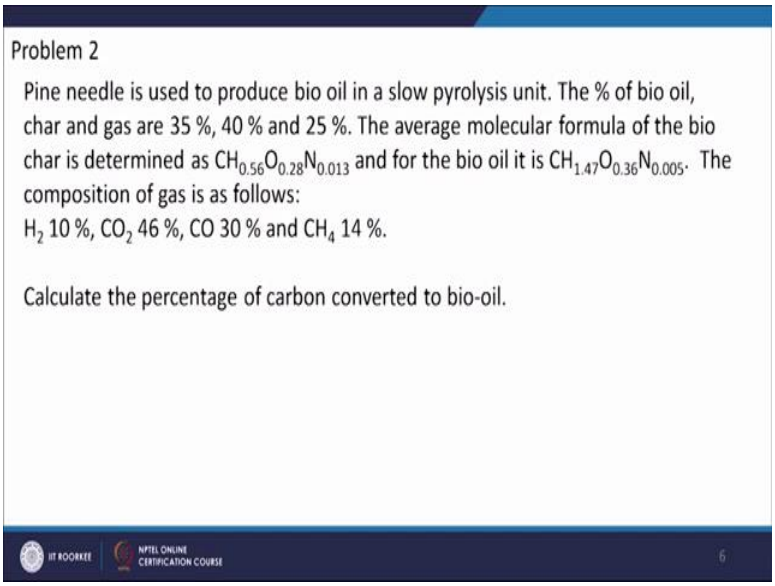

So, the statement of the next problem is pine needle is used to produce bio oil in a slow pyrolysis unit. The percentage of bio oil char and gas are 35 percent 40 percent and 25 percent. The average molecular formula of the bio char is determined as CH 0.56 O 0.28 N 0.013 and for the bio oil it is CH 1.47 O 0.36 N 0.005. The composition of the gas is as follows that hydrogen 10 percent CO 2 - 46 percent, CO - 30 percent, and CH 4 - 14 percent. Calculate the percentage of carbon converted to bio oil. So, in this problem pine needle is converted to bio oil gas and char through pyrolysis and the conversion is given into different fractions that is 35 percent, 40 percent and 25 percents, so bio oil char and gas respectively. And it is also given the molecule formula of the char as well as the bio oil, and also the gas composition the different components present in the gas stream is

also given. Now, we have to calculate the percentage of carbon converted into bio oil. So, if you get the total carbon, and how much carbon is present in the oil, then we can calculate this percentage conversion.

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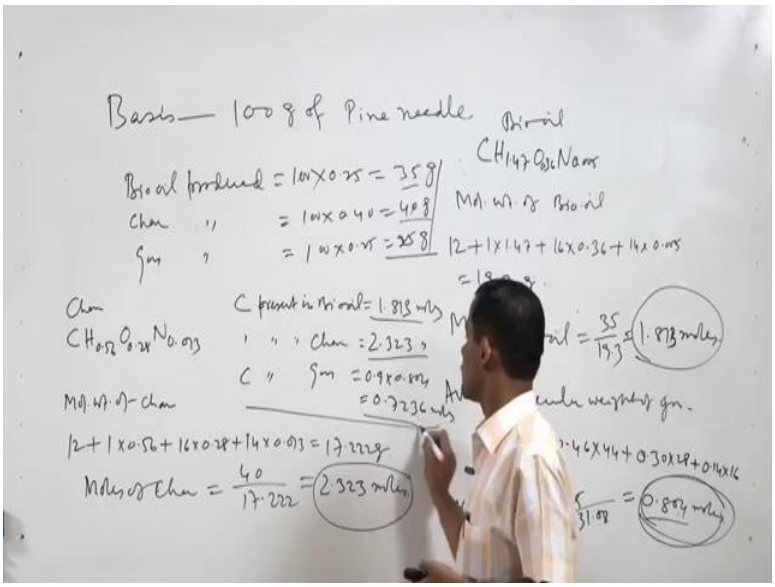

So, for solving this, we need to take one basis now let us take a basis of that is 100 gram of pine needle 100 gram of pine needle. So, as per the statement, bio oil equal to bio oil produced equal to 100 into 35 percent, so 0.35 that is equal to 35 gram. Similarly, how much char is produced that is equal to 40 percent, so char produce equal to 40 percent that is 40 gram. So, the remaining is our gas. So, how much gas is produced that equal to 100 into 25 percent, so 25, so 0.25, so 25 gram. So, this is our production of different components. Some information is given to us that is molecular weight of bio oil. So, molecular weight of bio oil that is equal to CH 1.47 O 0.36 and N 0.005 and N 0.005 that means, the char contains carbon, hydrogen, oxygen and nitrogen in these ratios.

Then what will be the molecular weight of this of bio oil this is bio oil or this is bio oil. So, this is for bio oil. So, molecular weight of bio oil, we can calculate that is equal to 12 plus 1 into 1.47 plus 16 into 0.36 plus 14 into 0.005, so that is equal to 19.3 gram. Now, we have got the molecular weight of this 19.3 gram that is for bio oil and how much bio oil we have got 35 gram. So, how many moles of so moles of bio oils we will get from 100 gram of the pine needle moles of bio oil is equal to 35 gram we have got. So, 35

divided by 19.3, so we will be getting 35 divided by 19.3 that is equal to 1.813 moles. So, these moles of bio oil is produced.

Similarly, for char, the formula is given for char molecular formula is given that is CH 0.56 O 0.28 and N is 0.013, so 0.013. Similarly, the molecule weight of char, we can calculate on the basis of this formula that is equal to 12 plus 1 into 0.56 plus 16 into 0.28 plus 14 into 0.013. So, then we will be getting 17.222 gram, so that is equal to 17.222 gram, but char we have got 40 gram. So, number of moles char we can calculate. So, number of moles of char we can calculate that is equal to moles of char divided by 40 divided by 17.222, so that is equal to 2.323 moles. So, now, we have got the moles of char produced and moles of bio oil produced.

Another information which is given here that the percentage of the different gas components in the gas stream. So, average molecular weight we can calculate of gas we are assuming that the gas component, which is given here is in volume basis. So, we will be getting here the mass average molecular rate of the gas that is equal to percentage of hydrogen, hydrogen is there that is 10, so 0.10 into 2 plus percentage of carbon dioxide that is 46 percent. So, 0.46 into 44 plus percentage of CO it is 30 percent. So, 0.3 into CO 28 and the CH 4 is equal to 0.14 into 16. So, this is equal to we are getting 31.08, so that is equal to 31.08. So, this 31.08, this is the average molecular weight of the gas stream.

So, how many moles of gas is produced, we have got 25 gram. So, moles of gas is equal to 25 divided by 31.08 that is equal to how much 0.804 moles. Now, we have got the moles of the gas. What is our objective, we have to calculate how much carbon is converted to bio oil. So, now, we have got the compositions of different products, and the amount of different products produced from 100 gram of the pine needle. Now, let us see, what will be the carbon present in bio oil.

So, bio oil, this is our bio oil. So, 1 mole of bio oil contains 1 mole of carbon. So, how many moles of bio oils we have got 1.813 moles of bio oil from 100 gram of pine needle. So, carbon present in bio oil equal to 1.813 moles. Similarly, carbon present in char. So, how many moles of char we are getting 2.323 moles. And if here 1 moles of char is containing 1 mole of carbon. So, here char is equal to 2.323 moles and carbon present in

gas is equal to how much we have got 0.804 moles of gas, and we have also got that the different carbon present in this gas molecule are in CO 2, CH 4 not in H 2.

So, H 2 is 10 percent, so remember remaining is 90 percent, so 90 percent will be present in it. So, 0.9 therefore, that will be 0.9 into this 0.804, this is 0.804 moles of gas molecules are present. So, 0.9 of it will be containing carbon, so that is equal to 0.9 into 0.804 or that we can get it for 0.7236, 0.7236 moles. So, these are the total carbon now we are getting this plus this one plus this one. And carbon present in liquid. Now, carbon present is oil that is equal to these moles. So, the conversion of carbon to oil is equal to 1.813 divided by 1.813 plus 2.323 plus 0.7236 that is equal to say 37.31 percentage will to multiply it by 100. So, we will get the percentage of carbon, which is converted into bio oil. So, this problem we have completed. And now we will end the discussion on this module.

Thank you very much for your patience.