Basic Environmental Engineering and Pollution Abatement
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Lecture – 55
Tutorial 11

Hello everyone. Now, we will have a tutorial session and, in this class, will solve some numerical problems based on our discussion made in the last four classes.

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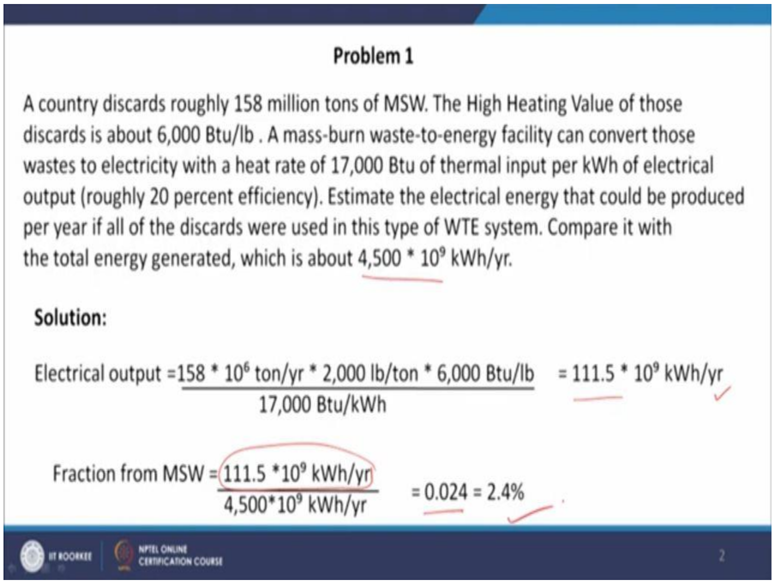

Problem number one, the statement is a country discards roughly 158 million tons of MSW. The high heating value of those discards is about 6000 Btu/lb. A mass burn waste-to-energy facility can convert those wastes to electricity with a heat rate of 17000 Btu of thermal input per kilowatt hour of electrical output; roughly 20 % efficiency. Estimate the electrical energy that could be produced per year if all the discards were used in this type of WTE system. Compare it with the total energy generated which is about $4500*10^9$ kWh/yr.

So, this is the problem statement; now we have to solve. So, what we will do? We will see that what is the electrical output we can get from this waste and then total electricity production which is provided here? So, we will be take the ratio of that.

$$\text{Electrical output} = \frac{158 * 10^6 \text{ ton/yr} * 2{,}000 \text{ lb/ton} * 6{,}000 \text{ Btu/lb}}{17{,}000 \text{ Btu/kWh}} = 111.5 * 10^9 \text{kWh/yr}$$

$$\text{Fraction from MSW} = \frac{111.5 * 10^9 \text{ kWh/yr}}{4{,}500 * 10^9 \text{ kWh/yr}} = 0.024 = 2.4\%$$

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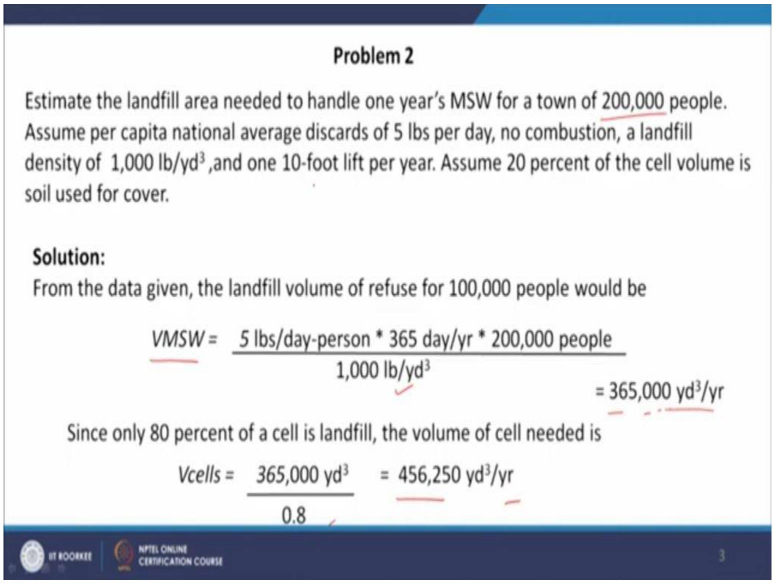

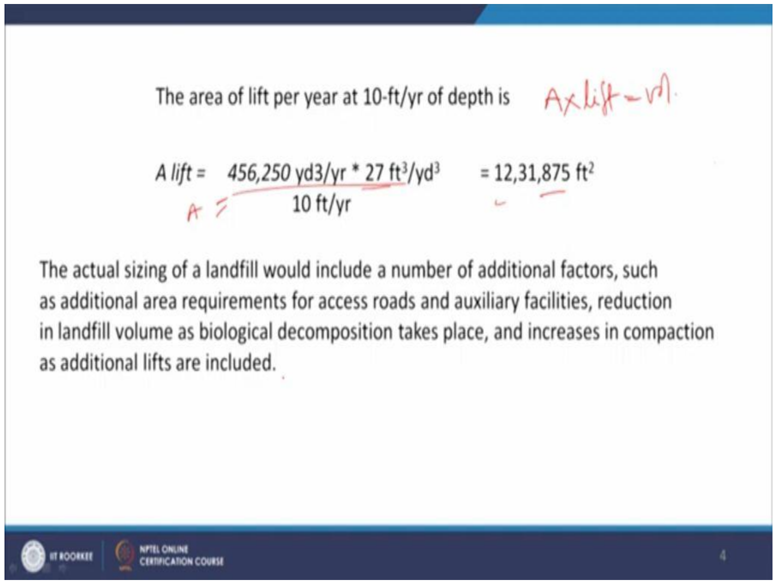

So, now we will move to problem number 2 and the statement is, estimate the landfill area needed to handle one year's MSW for a town of 2 lakhs people. Assume per capita national average discards of 5 lbs/day, no conversion. A landfill density of 1000 lb/yd^3 and one 10 feet lift per year. Assume 20 % of the cell volume is soil used for cover; so this is the problem statement. So, now we have to find out the area requirement for this landfilling. So, at first we will calculate the volume of the MSW, then we will see the volume of the cells, then lift is given. So, from that we will get the value of the area requirement.

From the data given, the landfill volume of refuse for 100,000 people would be

$$\text{VMSW} = \frac{5\ \text{lbs/day-person} * 365\ \text{day/yr} * 200{,}000\ \text{people}}{1{,}000\ \text{lb/yd3}} = 365{,}000\,\frac{\text{yd}^3}{\text{yr}}$$

Since only 80 percent of a cell is landfill, the volume of cell needed is

$$V_{\text{cell}} = \frac{365{,}000\,\frac{\text{yd}^3}{\text{yr}}}{0.8} = 456{,}250\ \frac{\text{yd}^3}{\text{yr}}$$

The area of lift per year at 10-ft/yr of depth is

$$\text{A lift} = \frac{456{,}250\ \frac{\text{yd}^3}{\text{yr}} * \ 456{,}250\ \frac{\text{ft}^3}{\text{yd}^3}}{10\,\frac{\text{ft}}{\text{yr}}} = 12{,}31{,}875\ \text{ft}^2$$

But, actually the area requirement will be more because there are some additional activities, which will be associated with the active filling.

So, the actual sizing of a landfill would include a number of additional factors such as additional area requirements for access roads and auxiliary facilities, reduction in landfill volume as biological decomposition takes place, and increases in compactions as additional lifts are included. So because of this, the actual requirement will be deferred to some extent from this one, and it will be more than this.

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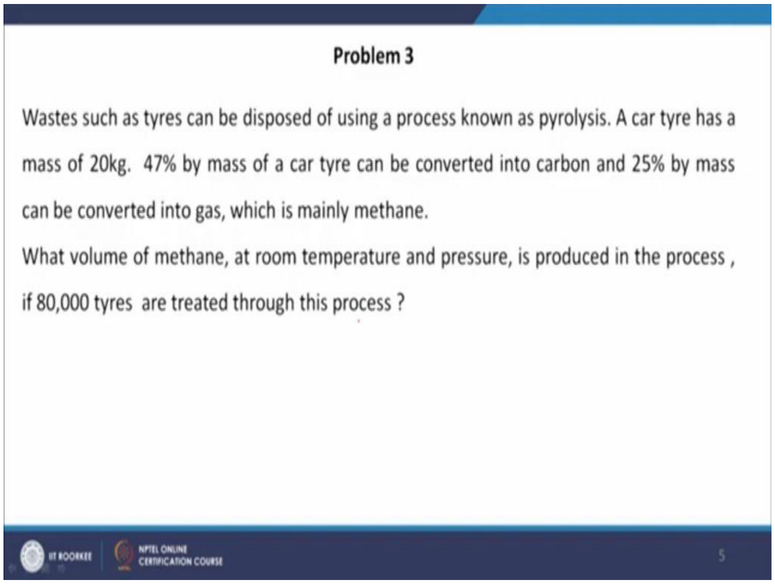

Now, problem number-3. The statement is, wastes such as tyres can be disposed of using a process known as pyrolysis. A car tyre has a mass of 20 kg. 47 % by mass of a car tyre can be converted into carbon and 25 % by mass can be converted into gas, which is mainly methane. What volume of methane, at room temperature and pressure is produced in the process, if 80,000 tyres are treated through this process? So, this is a problem statement of a pyrolysis process, waste tyre is converted to different pyrolysis products. And it is assumed that the gas which is produced only methane is present to make the calculation more simple.

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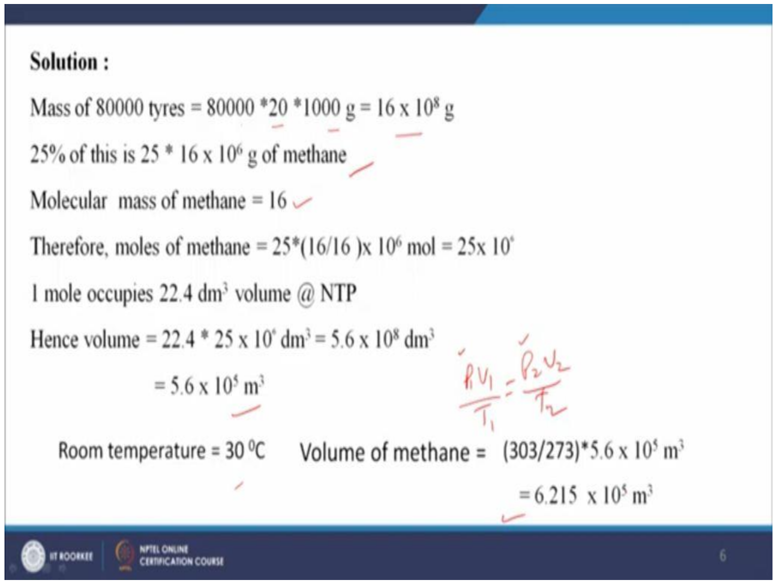

So, here we will have to do some mass balance.

Mass of 80000 tyres = 80000 *20 *1000 g = 16 x 10^8 g

25% of this is 25 * 16 x 10^6 g of methane

Molecular mass of methane = 16

Therefore, moles of methane = 25*(16/16)x 10^6 mol = 25x 10^6

1 mole occupies 22.4 dm^3 volume @ NTP

Hence volume = 22.4 * 25 x 10^6 dm^3 = 5.6 x 10^8 dm^3

= 5.6 x 10^5 m^3

Room temperature = 30 ^{0}C

Volume of methane = (303/273)*5.6 x 10^5 m^3

= 6.215 x 10^5 m^3

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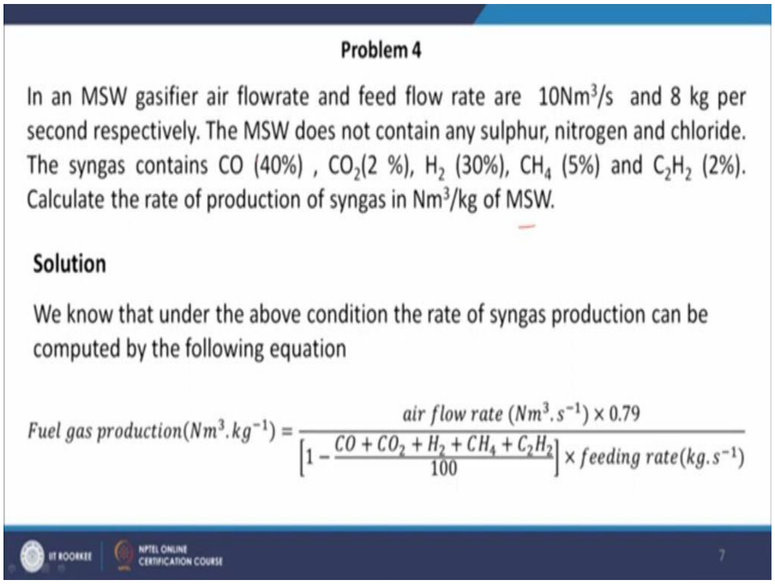

Now, problem number 4. The statement is, in an MSW gasifier air flow rate and feed flow rate are 10 Nm^3/s and 8 kg/s respectively. The MSW does not contain any sulphur, nitrogen and chloride. The syngas contains carbon monoxide 40 %, CO_2 2 %, H_2O 30 %, CH_4 5 % and C_2H_2 2 %. Calculate the rate of production of syngas in Nm^3/kg of MSW. So again, this is another problem related to the handling of MSW through gasifier. And through the gasifier, we know that producer gas or syngas, when we use the oxygen, we get syngas; and when we use the air, we get producer gas. So this is a case of producer gas production.

Now, what we will see? This is also again, can be solved on the basis of mass balance of nitrogen.

We know that under the above condition the rate of syngas production can be computed by the following equation

$$\text{Fuel gas production}\left(\frac{Nm^3}{kg}\right) = \frac{\text{Air flow rate}\left(\frac{Nm^3}{s}\right)}{[1-(CO+CO_2+H_2+CH_4+C_2H_2)/100] \times \text{Feeding rate}\left(\frac{kg}{s}\right)}$$

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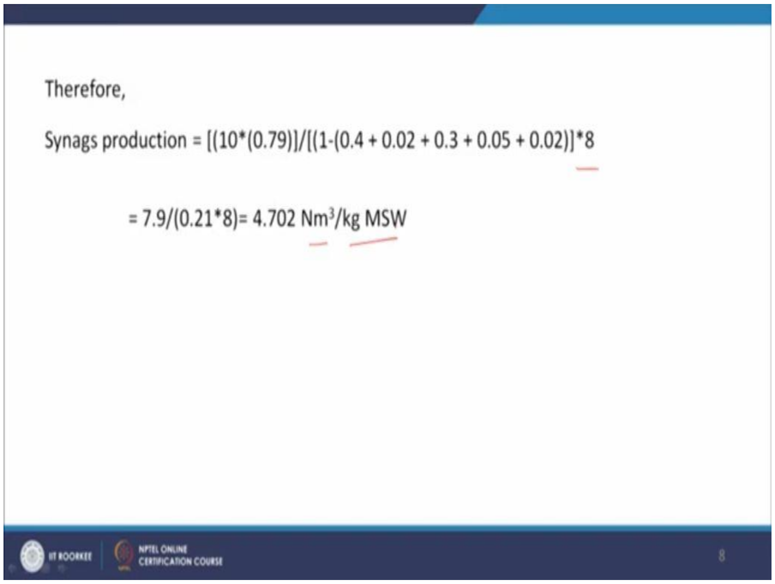

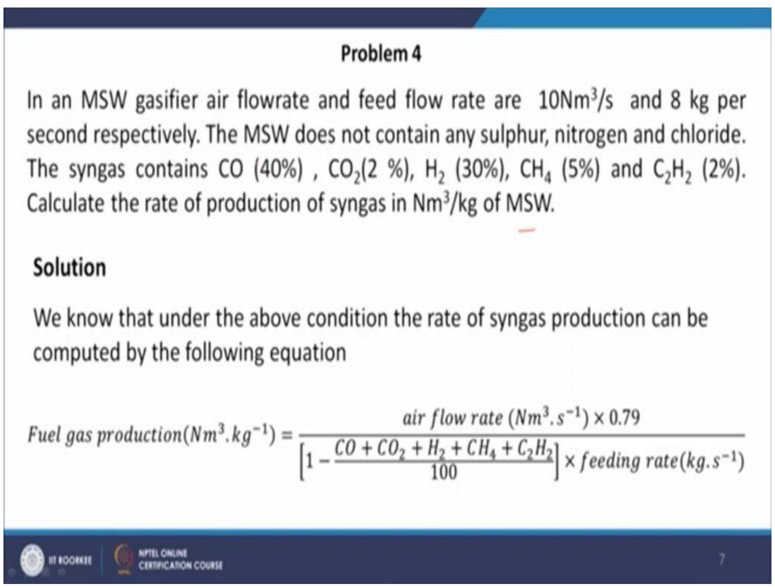

Synags production = [(10*(0.79)]/[(1-(0.4 + 0.02 + 0.3 + 0.05 + 0.02)]*8

= 7.9/(0.21*8)= 4.702 Nm^3/kg MSW

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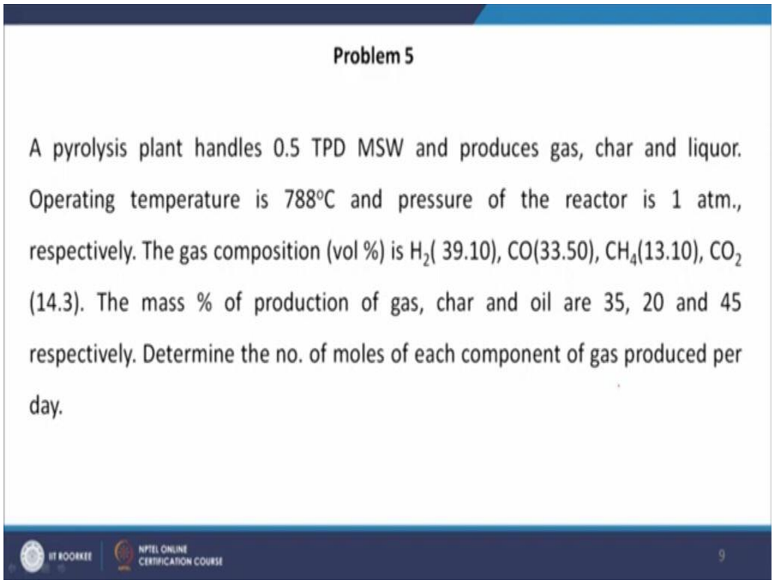

Next problem, statement number 5. A pyrolysis plant handles 0.5 TPD MSW and produces gas, char and liquor. Operating temperature is 788 ^oC and pressure of the reactor is 1 atmosphere respectively. The gas composition volume percent is H_2 (39.10), CO (33.50), CH_4 (13.10), CO_2 (14.3). The mass % of production of gas, char and oil are 35, 20 and 45 respectively. Determine the number of moles of each component of gas produced per day. So, we have to calculate the number of moles of each component of gas produced per day. So, this is a problem related to pyrolysis of MSW.

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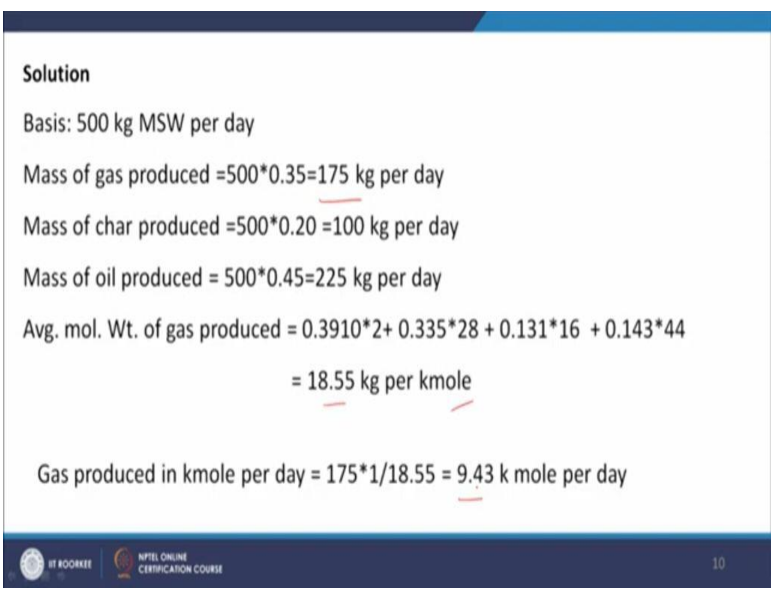

Basis: 500 kg MSW per day

Mass of gas produced =500*0.35=175 kg per day

Mass of char produced =500*0.20 =100 kg per day

Mass of oil produced = 500*0.45=225 kg per day

Avg. mol. Wt. of gas produced = 0.3910*2+ 0.335*28 + 0.131*16 + 0.143*44

= 18.55 kg per kmole

Gas produced in kmole per day = 175*1/18.55 = 9.43 k mole per day

So, this is the gas production per day.

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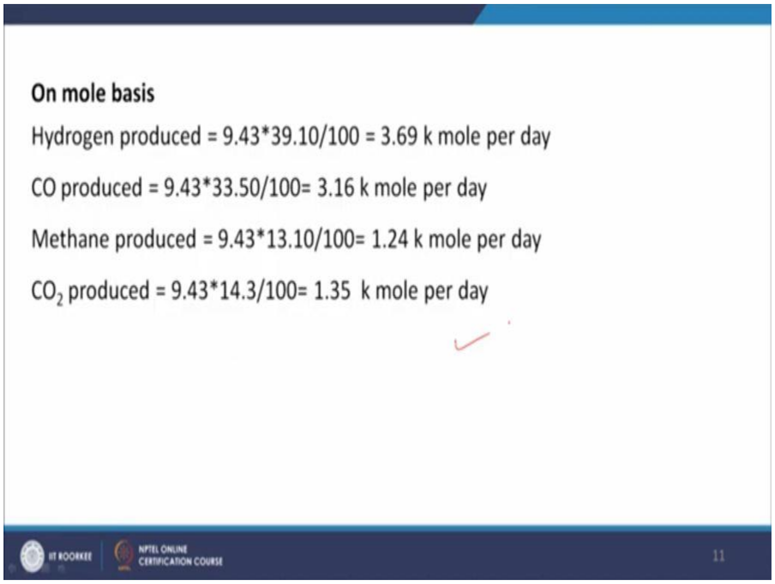

Now, we have to calculate individual gas molecules production per day.

On mole basis

Hydrogen produced = 9.43*39.10/100 = 3.69 k mole per day

CO produced = 9.43*33.50/100= 3.16 k mole per day

Methane produced = 9.43*13.10/100= 1.24 k mole per day

CO_2 produced = 9.43*14.3/100= 1.35 k mole per day

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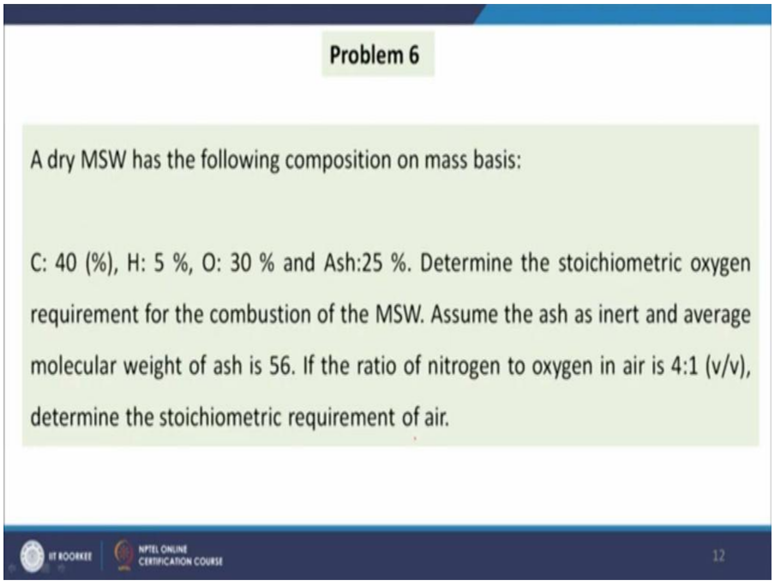

Now, we will move to the next problem, problem number 6. The statement is a dry MSW has the following composition on mass basis; carbon 40 %, hydrogen 5 %, oxygen 30 %, ash 25 %. Determine the stoichiometric oxygen requirement for the combustion of the MSW. Assume the ash as inert and average molecular weight of ash is 56. If the ratio of nitrogen to oxygen in air is 4:1 volume by volume ratio; determine the stoichiometric requirement of air. So, this problem is basically related to the incineration of MSW; so we have to calculate the stoichiometric requirement of air.

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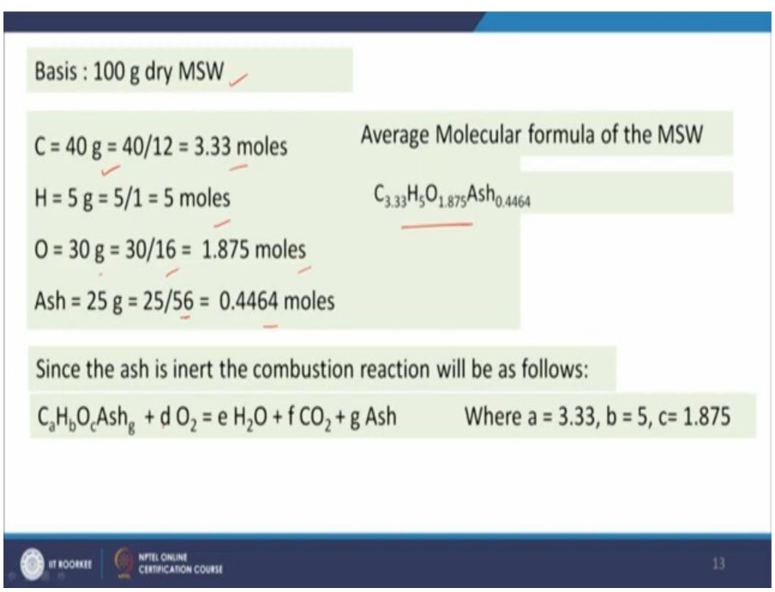

Basis : 100 g dry MSW

C = 40 g = 40/12 = 3.33 moles

H = 5 g = 5/1 = 5 moles

O = 30 g = 30/16 = 1.875 moles

Ash = 25 g = 25/56 = 0.4464 moles

Average Molecular formula of the MSW

$C_{3.33}H_5O_{1.875}Ash_{0.4464}$

Since the ash is inert the combustion reaction will be as follows:

$C_aH_bO_cAsh_g + d\ O_2 = e\ H_2O + f\ CO_2 + g\ Ash$

Where a = 3.33, b = 5, c= 1.875

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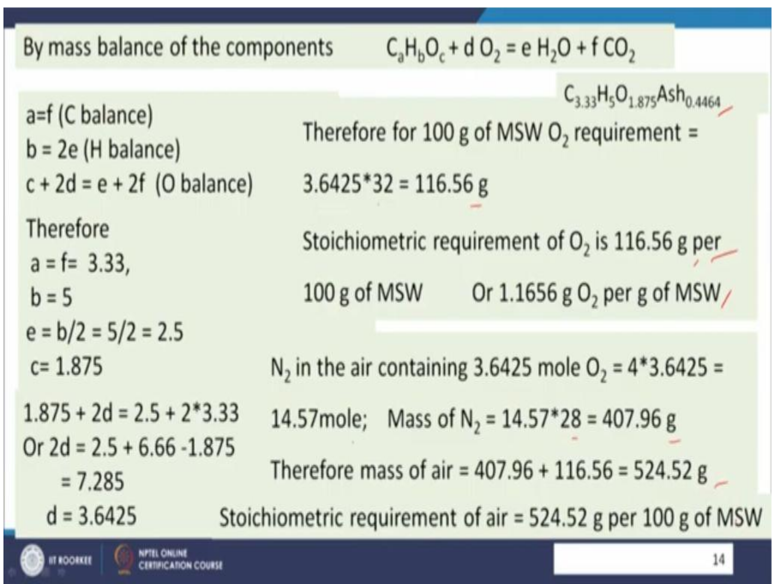

By mass balance of the components

$C_aH_bO_c + d\ O_2 = e\ H_2O + f\ CO_2$

a=f (C balance)

b = 2e (H balance)

c + 2d = e + 2f (O balance)

$C_{3.33}H_5O_{1.875}Ash_{0.4464}$

Therefore

a = f= 3.33,

b = 5

e = b/2 = 5/2 = 2.5

c= 1.875

1.875 + 2d = 2.5 + 2*3.33

Or 2d = 2.5 + 6.66 -1.875

= 7.285

d = 3.6425

Therefore for 100 g of MSW O_2 requirement = 3.6425*32 = 116.56 g

Stoichiometric requirement of O_2 is 116.56 g per 100 g of MSW

Or 1.1656 g O_2 per g of MSW

N_2 in the air containing 3.6425 mole O_2 = 4*3.6425 = 14.57mole;

Mass of N_2 = 14.57*28 = 407.96 g

Therefore mass of air = 407.96 + 116.56 = 524.52 g

Stoichiometric requirement of air = 524.52 g per 100 g of MSW

So, now we are able to solve the problem and we have seen the stoichiometric requirement of air. So, now we have solved all our problems and thank you for your patience.