



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

WASTE TO ENERGY CONVERSION

TUTORIAL ON PYROLYSIS

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Problem 1

A fast pyrolysis plant handles 1TPD MSW and produces gas, char and liquor. Operating temperature and pressure of the reactor are 788°C and 1 atm., respectively. The gas composition (vol %) is H_2 (37.16), CO(35.50), CH_4 (11.10), CO_2 (16.3). The mass % of production of gas, char and oil are 30, 25 and 45 respectively. Determine the product distribution with individual component of gas and the rate of hydrogen production assuming 90 % separation efficiency for hydrogen.



Solution

Basis: 1000 kg MSW per day

Mass of gas produced = $1000 \times 0.3 = 300$ kg per day

Mass of char produced = $1000 \times 0.25 = 250$ kg per day

Mass of oil produced = $1000 \times 0.45 = 450$ kg per day

Avg. mol. Wt. of gas produced = $0.3716 \times 2 + 0.355 \times 28 + 0.111 \times 16 + 0.163 \times 44$
= 19.61 kg per kmole

Gas produced in kmole per day = $300 \times 1 / 19.61 = 15.295$ kmole per day



On mole basis

Hydrogen produced = $15.295 \times 37.16 / 100 = 5.68$ kmole per day

CO produced = $15.295 \times 35.5 / 100 = 5.425$ kmole per day

Methane produced = $15.295 \times 11.11 / 100 = 1.695$ kmole per day

CO₂ produced = $15.295 \times 16.3 / 100 = 2.49$ kmole per day

On mass basis

Hydrogen produced = $2 \times 5.68 = 11.36$ kg per day

CO produced = $28 \times 5.425 = 151.91$ kg per day

Methane produced = $16 \times 1.695 = 27.12$ kg per day

CO₂ produced = $44 \times 2.49 = 109.56$ kg per day



Volume basis @ 788 °C and 1 atm

$$\begin{aligned}\text{Hydrogen produced} &= 5.68 * 1000 * (22.4/1000) * (1061/273) * (1/24) \\ &= 5.68 * 3.627 = 20.6035 \text{ m}^3 \text{ per hour}\end{aligned}$$

$$\text{CO produced} = 5.425 * 1000 * (22.4/1000) * (1061/273) * (1/24) = 19.678 \text{ m}^3 \text{ per hour}$$

$$\text{Methane produced} = 1.695 * 1000 * (22.4/1000) * (1061/273) * (1/24) = 6.1485 \text{ m}^3 \text{ per hour}$$

$$\text{CO}_2 \text{ produced} = 2.49 * 1000 * (22.4/1000) * (1061/273) * (1/24) = 9.032 \text{ m}^3 \text{ per hour}$$

Since the hydrogen separation efficiency is 90 %

$$\text{Actual Hydrogen produced} = 20.6035 * 0.90 = 18.54 \text{ m}^3 \text{ per hour}$$



Problem 2

Pine needle is used to produce bio oil in a slow pyrolysis unit. The % of bio oil, char and gas are 35 %, 40 % and 25 %. The average molecular formula of the bio char is determined as $\text{CH}_{0.56}\text{O}_{0.28}\text{N}_{0.013}$ and for the bio oil it is $\text{CH}_{1.47}\text{O}_{0.36}\text{N}_{0.005}$. The composition of gas is as follows:

H_2 10 %, CO_2 46 %, CO 30 % and CH_4 14 %.

Calculate the percentage of carbon converted to bio-oil.



Basis : 100 g pine needle

Bio oil produced = 35 g

Char produced = 40 g

Gas produced = 25 g

Molecular weight of Char ($\text{CH}_{0.56}\text{O}_{0.28}\text{N}_{0.013}$) is
 $= 12 + 1*0.56 + 16*0.28 + 14*0.013 = 17.222 \text{ g}$

Thus, 40 g char = $40/17.222$ moles = 2.323 moles

Average molecular weight of the gas =
 $0.1 * 2 + 0.46*44 + 0.3 * 28 + 0.14*16 = 31.08$

Thus 25 g gas = $25/31.08$ mole = 0.804 mole gas

Molecular weight of bio oil ($\text{CH}_{1.47}\text{O}_{0.36}\text{N}_{0.005}$) is
 $= 12 + 1*1.47 + 16*0.36 + 14*0.005 = 19.3 \text{ g}$

Thus, 35 g bio oil = $35/19.3$ moles = 1.813 moles

Vol % / mole % of gas
components

H_2 10 %, CO_2 46 %, CO 30 %
 CH_4 14 %.

Thus, one mole of gas contains
0.1 mole H_2
0.46 mole CO_2
0.3 mole CO and
0.14 mole CH_4

Now C present in bio oil = 1.813 moles

C present in char = 2.323 moles

C present in gas = $(0.804 \times (0.46 + 0.3 + 0.14)) =$
 $0.804 \times 0.9 = 0.7236$ moles

Total carbon = $1.813 + 2.323 + 0.7236$ moles = 4.8596 moles

% of C converted to bio oil = $1.813 \times 100 / 4.8596 = 37.31$ %



Problem 3

A car tyre has a mass of 10kg. Tyres can be disposed of using a process known as pyrolysis. 41% by mass of a car tyre can be converted into carbon and 22% by mass can be converted into gas, which is predominantly methane.

If 90000 tyres are treated in this way each year in a city. What volume of methane, at room temperature and pressure, is produced in this process?



Solution :

Mass of 90000 tyres = $90000 \times 10 \times 1000 \text{ g} = 9 \times 10^8 \text{ g}$

22% of this is $22 \times 9 \times 10^6 \text{ g}$ of methane

Molecular mass of methane = 16

Therefore, moles of methane = $22 \times (9/16) \times 10^6 \text{ mol} = 1.2374 \times 10^7$

1 mole occupies 22.4 dm^3 volume @ NTP

Hence volume = $22.4 \times 1.2374 \times 10^7 \text{ dm}^3 = 2.77 \times 10^8 \text{ dm}^3$
 $= 2.77 \times 10^5 \text{ m}^3$

Room temperature = 30°C Volume of methane = $(303/273) \times 2.77 \times 10^5 \text{ m}^3$
 $= 3.07 \times 10^5 \text{ m}^3$



Thanks...

