



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

WASTE TO ENERGY CONVERSION

TUTORIAL ON TRANSESTERIFICATION

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Problem 1.

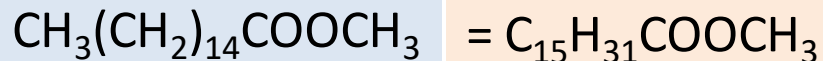
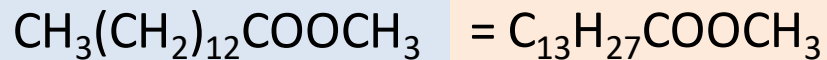
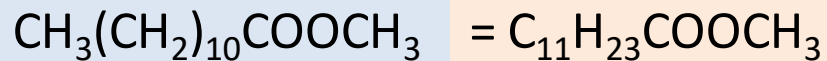
Bio oil extracted from an oil seed sample has 90 % triglycerides containing three long chains, which can produce methyl esters of lauric acid ($\text{CH}_3(\text{CH}_2)_{10}\text{COOH}$), myristic acid ($\text{CH}_3(\text{CH}_2)_{12}\text{COOH}$) and palmitic acid ($\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$) 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 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?



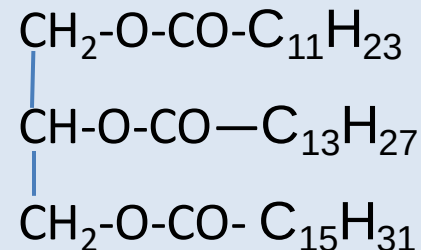
Solution

Transesterification produces methyl esters of lauric acid ($\text{CH}_3(\text{CH}_2)_{10}\text{COOH}$), myristic acid ($\text{CH}_3(\text{CH}_2)_{12}\text{COOH}$) and palmitic acid ($\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$)

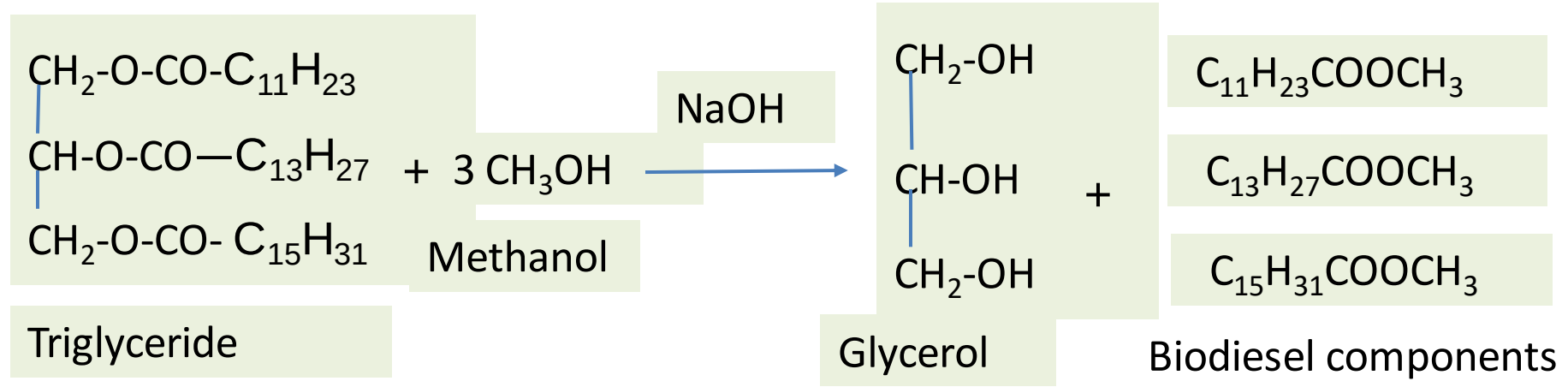
Therefore, the produced methyl esters are



Thus, formula of the oil is



Transesterification reaction



Molecular weight of the triglyceride

$$= 12 \cdot 45 + 1 \cdot 86 + 6 \cdot 16 = 722 \text{ g}$$

Molecular weight of glycerol

$$= 12 \cdot 3 + 1 \cdot 8 + 3 \cdot 16 = 92 \text{ g}$$

Molecular weight of $C_{11}H_{23}COOCH_3$

$$= 12 \cdot 13 + 1 \cdot 26 + 16 \cdot 2 = 214 \text{ g}$$

Molecular weight of $C_{13}H_{27}COOCH_3$

$$= 12 \cdot 15 + 1 \cdot 30 + 16 \cdot 2 = 242 \text{ g}$$

Molecular weight of $C_{15}H_{31}COOCH_3$

$$= 12 \cdot 17 + 1 \cdot 34 + 16 \cdot 2 = 270 \text{ g}$$

Basis : 10 kg bio oil

$$\text{Triglyceride} = 10 \cdot 0.9 = 9 \text{ kg}$$

$$\text{Moles of triglyceride in the oil} = 9 / 0.722 \text{ mole} = 12.465 \text{ mole}$$

$$\text{Moles of triglyceride converted into glycerine} = 12.465 \cdot 0.7 = 8.7258 \text{ moles}$$

$$\text{Glycerine produced} = 8.7258 \cdot 0.092 \text{ kg} = 0.803 \text{ kg}$$



$$\text{Mass of produced } C_{11}H_{23}COOCH_3 = 8.7258 \times 0.214 = 1.867 \text{ kg}$$

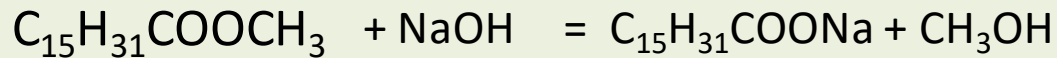
$$\text{Mass of produced } C_{13}H_{27}COOCH_3 = 8.7258 \times 0.242 = 2.112 \text{ kg}$$

$$\text{Mass of produced } C_{15}H_{31}COOCH_3 = 8.7258 \times 0.270 \times 0.9 = 2.120 \text{ kg}$$

$$C_{15}H_{31}COOCH_3 \text{ used for soap formation} = 8.7258 \times 0.270 \times 0.1 \text{ kg} = 0.2356 \text{ kg}$$

$$\text{Mass of biodiesel} = 1.867 + 2.112 + 2.120 = 6.099 \text{ kg}$$

Reaction for soap formation



270 g

278 g

$$\begin{aligned} \text{Thus, soap produced} \\ = 278 \times 0.2356 / 270 = 0.2426 \text{ kg} \end{aligned}$$

$$\text{Molecular weight of soap} = 12 \times 16 + 1 \times 31 + 2 \times 16 + 23 = 278 \text{ g}$$

Heterogeneous catalyst
for high performance

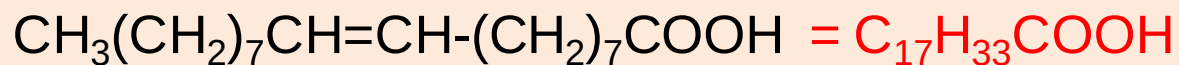


Problem 2.

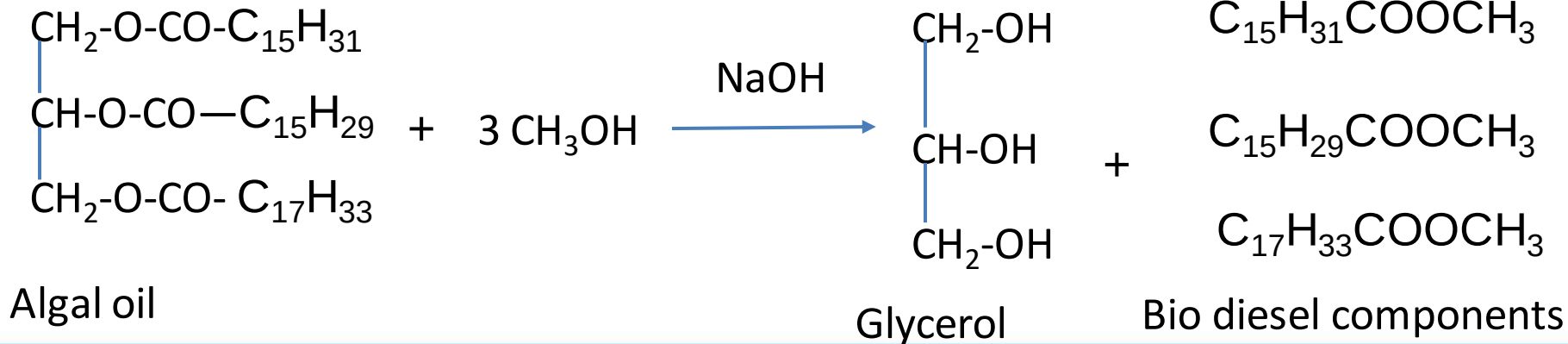
Oil content in *Cyanobacteria* determined through Bligh and Dyer's Method is 70 % of its dry biomass. The oil after transesterification with methanol in presence of alkali catalysts can produce methyl esters of $\text{CH}_3-(\text{CH}_2)_{14}-\text{COOH}$, $\text{CH}_3(\text{CH}_2)_5\text{CH}=\text{CH}-(\text{CH}_2)_7\text{COOH}$ and $\text{CH}_3(\text{CH}_2)_7\text{CH}=\text{CH}-(\text{CH}_2)_7\text{COOH}$ acids, 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 % conversion in transesterification process and 100 % efficiency of the extraction process.



Solution


$$\begin{array}{l} \text{CH}_2\text{-O-CO-C}_{15}\text{H}_{31} \\ | \\ \text{CH-O-CO-C}_{15}\text{H}_{29} \\ | \\ \text{CH}_2\text{-O-CO-C}_{17}\text{H}_{33} \\ \text{(C}_{53}\text{H}_{98}\text{O}_6\text{)} \end{array}$$

Transesterification reaction



Basis : Mass of algae = 50 kg

Since oil content is 70 %

Mass of oil = $50 * 0.70 = 35$ kg

Molecular weight of algal oil ($C_{53}H_{98}O_6$)

$$= 12*53 + 1*98 + 16*6 = 830 \text{ g}$$

Moles of algal oil produced from 50 kg algal biomass = $35/830 = 0.04217$ kg mole

Now 90 % of the algal oil is converted to biodiesel

Extraction efficiency = 100%

Hence,

Moles of algal oil converted to biodiesel = $0.04217 * 0.9 = 0.03795$ kg moles = 31.5 kg

Molecular weight of bio diesel components are:

$$C_{15}H_{31}COOCH_3 = 12*17 + 1*34 + 16*2 = 270 \text{ g}$$

$$C_{15}H_{29}COOCH_3 = 12*17 + 1*32 + 16*2 = 268 \text{ g}$$

$$C_{17}H_{33}COOCH_3 = 12*19 + 1*36 + 16*2 = 296 \text{ g}$$



Since, 1 mole of algal oil produces 1 mole each of the biodiesel components (methyl ester of fatty acids), the amount of each biodiesel component = 0.03795 kg moles

Thus, the mass of the produced biodiesel components are as follows:

$$\text{Mass of } C_{15}H_{31}COOCH_3 = 0.03795 \times 270 = 10.24 \text{ kg}$$

$$\text{Mass of } C_{15}H_{29}COOCH_3 = 0.03795 \times 268 = 10.17 \text{ kg}$$

$$\text{Mass of } C_{17}H_{33}COOCH_3 = 0.03795 \times 296 = 11.23 \text{ kg}$$

$$\text{Total biodiesel produced} = 10.24 + 10.17 + 11.23 = 31.64 \text{ kg}$$

As per the reaction one mole bio oil produces one mole of glycerine

$$\text{Thus, glycerine produced} = 0.03795 \text{ kg moles} = 0.03795 \times 92 = 3.49 \text{ kg}$$

$$\text{Molecular weight of glycerine}(C_3H_8O_3) = 12 \times 3 + 1 \times 8 + 3 \times 16 = 92 \text{ g}$$



Problem 3

50 g of a waste cooking oil was fully dissolved in some amount of neutralized ethanol by heating and titrated with N/10 KOH solution using phenolphthalein indicator. If the titre value is 100 ml. Determine the acid value of the oil.

Solution

As we know

$$S = \frac{56.1 \cdot V \cdot c}{m}$$

where S is the acid value (mg KOH/g WCO);
 c is the concentration of the KOH used for titration (mol/L);
 V is the volume of KOH employed for titration (mL);
 m is the weight of the sample taken to be analyzed (g).

Thus , for the present case

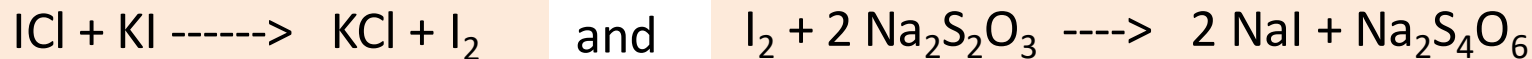
$$S = 56.1 \cdot 100 \cdot 0.1 / 50 = 11.22 \text{ (mg KOH /g bio oil)}$$

Problem 4

A 200 ml bio oil sample is reacted with 81 g iodide 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. Determine the iodine value of the oil.

Solution

The excess ICl will react with KI and form I_2 , which will further be converted to I as per the following reactions:



From the above reaction it seems that 0.2 mole thiosulphate reacts with 0.1 mole I_2
 $= 253.8 \times 0.1 = 25.38 \text{ g } I_2$

Iodine present in original ICl solution = $81 \times 126.9 / 162.35 = 63.31 \text{ g}$

Iodine used by the 200 ml oil = $63.31 - 25.38 = 37.93 \text{ g}$, **Thus, iodine value of the oil = 19**



Thanks

