module - 5
FUEL

process of burning

Fuel: a fuel is combustible substance which undergoes combustion in the presence of air to produce a large amount of heat, that can be used economically for domestic and industrial purpose.

$Fuel + O_2 \rightarrow$ Product + Heat

major constituent particles: Hydrogen and Carbon

Classification

on the basis of occurrance

- Primary or Natural fuel
- Secondary or Artificial fuel

Note:- derive from primary fuel

physical state	primary or Natural fuel	Secondary or Artifical fuel
Solid	wood, coal	wood charcoal
	lignite	coke, pulverized coal (choornit coal)
liquid	crude oil	kerosene oil
	Petroleum	Diesel oil, petrol
Gaseous	Natural gas	Coal gas, water gas, producer gas, biogas, LPG

Characteristics of good fuel :-

- High Calorific value
- moderate ignition temperature
- Should be available in
  - Bulk
  - easily
  - cheapy
- It should not undergoes spontaneous ~~combination~~ combustion
- Should have low moisture content.
- It should have moderate rate of combustion
- Its combustion should be under control
- It should not produce objectionable gases.
- It should have low moisture content as it will reduce the calorific value of fuel

The efficiency of fuel is Judged by it Calorific value.

It is important property of fuel

Calorific Value

It is also known as Heat of Combustion

"Total amount of heat liberated, when unit mass/volume of the fuel burnt completely"

Two type

Higher or Gross Calorific Value (H.C.V) OR (G.C.V)

→ The amount of Heat liberated when unit mass/volume of the fuel burnt completely and product of combustion have been cooled at 15°C to 60°F

Lower or Net Calorific Value (L.C.V) OR (N.C.V)

The amount of Heat liberated when unit mass/volume of the fuel burnt completely and product of combustion are allowed to escape.

$\boxed{LCV = H.C.V - \text{Latent Heat of water vapour form}}$

fuel

$H_2 + \frac{1}{2}O_2 \longrightarrow H_2O$

1 Parts   9 parts

Or

given in form of percentage

$\boxed{L.C.V = H.C.V - \text{weight of hydrogen in fuel} \times 9 \times \text{latent heat of steam}}$

{latent Heat of steam = 587 cal/gm}

Units of Calorific Value

Calorie

- the amount of Heat required to raise the temperature of $\boxed{1gm}$ of water by $\boxed{1^\circ C}$.

Kilocalorie

- the amount of heat required to raise the temperature of $\boxed{1kg}$ of water by $\boxed{1^\circ C}$

British Thermal unit (B.T.U)

- The amount of heat required to raise temperature of 1 pound (lb) of water by $1^\circ F$

Centigrade Heat Unit (C.H.U)

- The amount of Heat required to raise temperature of 1 pound of water by $1^\circ C$.

2 # Relation in units of Calorific value

$1 Kcal = 1000 cal = (3.96)\ B.T.U = (2.2)\ C.H.U$

3

Dulong's formula :

Formula → $HCV = \frac{1}{100}\left[8080\,C + 34500\left(H - \frac{O}{8}\right) + 2240\,S\right]$ Kcal/kg

unit = Calorific value of kcal/kg or cal/gm

Calorific value of carbon = 8080 cal/gm

— " — of Hydrogen = 34500 cal/gm

— " — of Sulphur = 2240 cal/gm

$LCV = \left[HCV - \frac{9}{100} \times \%\text{mass of Hydrogen} \times \text{Latent Heat of steam}\right]$

$LCV = \left[HCV - \frac{9}{100} \times \text{mass of (H)} \times 587\right]$ kcal/kg

Numerical

(1) C = 60%, O_2 = 33%, H_2 = 6%. S = 0.5%. N_2 = 0.3%. and ash = 0.2% calculate the HCV and NCV of coal assuming that the latent heat of water vapour is 587 kcal/kg (L.C.V)

$\Rightarrow$

$$H.C.V = \frac{1}{100}\left[8080\,C + 34500\left(H - \frac{O}{8}\right) + 2240 \times S\right] \text{kcal/kg}$$

$$= \frac{1}{100}\left[8080 \times 60 + 34500\left(6 - \frac{33}{8}\right) + 2240 \times 0.5\right]$$

$$= \frac{1}{100}\left[484800 + 34500(6 - 4.125) + 1120\right]$$

$$= \frac{1}{100}\left[484800 + 34500 \times 1.875 + 1120\right]$$

$$= \frac{484800 + 64687.5 + 1120}{100} = \frac{550607.5}{100}$$

$$\boxed{HCV = 5506.07 \text{ kcal/kg}}$$

$$N.C.V = L.C.V = \left[H.C.V - \frac{9 \times H}{100} \times 587\right] = \left[5506.07 - \frac{9 \times 6}{100} \times 587\right]$$

$$= \left[5506.07 - 316.98\right]$$

$$\boxed{L.C.V = 5189.09 \text{ kcal/kg}}$$

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(2) Calculate the gross and net calorific values of coal having the following composition :
Carbon = 85% ; Hydrogen = 8 % ; Sulphur = 1% ; nitrogen = 2% ; ash = 4% , latent heat of steam = 587 cal/gm

⇒ C = 85%
H = 8%
S = 1%
} amount of heat liberated by complete combustion only due the C, H, S

N = 2%

Not given → (oxygen) O = 100 − [85 + 8 + 1 + 2 + 4] ← add all constituents present
O = 100 − 100 = 0 %

By applying Dulong formula

$$HCV = \frac{1}{100}\left[8080\,C + 34500\left[H - \frac{O}{8}\right] + 2240 \times S\right] \text{kcal/kg}$$

$$= \frac{1}{100}\left[8080 \times (85) + 34500\left[8 - \frac{(0)}{8}\right] + 2240 \times 1\right] \text{kcal/kg}$$

$$= \frac{1}{100}\left[686800 + 34500[8] + 2240\right]$$

$$= \frac{686800 + 276000 + 2240}{100} = \frac{965040}{100}$$

$$\boxed{HCV = 9650.40 \text{ kcal/kg}}$$

$$L.C.V = H.C.V - 9 \times \text{mass of hydrogen} \times \text{latent heat}$$

$$= 965040 - 9 \times 8\% \times 587$$

$$= 9650.4 - \frac{9 \times 8 \times 587}{100} = 9650.4 - 422.64$$

$$\boxed{LCV = 9227.76 \text{ kcal/kg}}$$

(4) A coal having following composition by weight C = 70%, O = 8.0%, H = 10%, S = 2.0%, N = 0.5% and ash = 7.0%. Calculate HCV and LCV by Dulong formula

=>

$$HCV = \frac{1}{100}\left[8080 \times C + 34500\left(H - \frac{O}{8}\right) + 2240 \times S\right] \frac{kcal}{kg}$$

$$= \frac{1}{100}\left[8080 \times 70 + 34500\left(10 - \frac{8}{8}\right) + 2240 \times 2\right] \frac{kcal}{kg}$$

$$= \frac{1}{100}\left[565600 + 34500(9) + 4480\right]$$

$$= \frac{570080 + 34500 \times 9}{100} \ kcal/kg = \frac{570080 + 310500}{100}$$

$$\boxed{HCV = \frac{\cancel{5700.80}\ 8805.80\ kcal}{kg}}$$

L.C.V = H.C.V − 9 × mass of H × latent heat of steam

$$LCV = \cancel{5700.8}\ 8805.80 - 9 \times 10\% \times 587$$

$$= 8805.80 - \frac{9 \times 10}{100} \times 587$$

$$= 8805.8 - 528.3$$

$$\boxed{LCV = 8277.5\ kcal/kg}$$

(5) A coal having following composition by weight C = 61%, O = 32%, H = 6%, S = 0.5%, N = 2% and ash = 4.0%. Calculate GCV and NCV by Dulong and petits formula.

=>

$$HCV = \frac{1}{100}\left[8080 \times C + 34500\left[H - \frac{O}{8}\right] + 2240 \times S\right] \frac{kcal}{kg}$$

$$= \frac{1}{100}\left[8080 \times 61 + 34500\left[6 - \frac{32}{8}\right] + 2240 \times 0.5\right]$$

$$= \frac{1}{100}\left[492880 + 34500\times(6-4) + 1120\right]$$

$$= \frac{1}{100}\left[492880 + 69000 + 1120\right]$$

$$= \frac{563000}{100} \quad \boxed{HCV = 5630.00 \frac{kcal}{kg}}$$

$$LCV = \left[H.CV - \frac{9\times H}{100} \times 587\right]$$

$$= \left[5630.00 - \frac{9\times 6}{100} \times 587\right]$$

$$= \left[5630 - 316.98\right]$$

$$\boxed{LCV = 5313.02 \frac{kcal}{kg}}$$

(6) Calculate the gross and net calorific value of coal having following compositions: C = 80% H = 7%, O = 3% S = 3.5% N = 2.1% and ash = 4.4%

$\Rightarrow$

$$HCV = \frac{1}{100}\left[8080\times C + 34500\left[H - \frac{O}{8}\right] + 2240\times S\right] \frac{kcal}{kg}$$

$$= \frac{1}{100}\left[8080\times 80 + 34500\left[7 - \frac{3}{8}\right] + 2240\times 3.5\right]$$

$$= \frac{1}{100}\left(646400 + 34500\,(6.625) + 7840\right]$$

$$= \frac{882802.5}{100}$$

$$\boxed{HCV = 8828.02\ kcal/kg}$$

$$LCV = \left[HCV - \frac{9}{100} \times H \times 587\right]$$

$$= \left[8828.02 - \frac{9 \times 7 \times 587}{100}\right]$$

$$= \left[8828.02 - 369.81\right]$$

$$\boxed{LCV = 8458.21 \ kcal/kg}$$

(7) A coal having following composite by weight C = 60%, O = 32%, H = 6%, S = 1%, N = 0.3% and ash = 3%. Calculate GCV and NCV by Dulong and petits formula

$$\Rightarrow \quad HCV = \frac{1}{100}\left[8080 \times C + 34500\left(H - \frac{O}{8}\right) + 2240 \times S\right] \frac{kcal}{kg}$$

$$= \frac{1}{100}\left[8080 \times 60 + 34500\left(6 - \frac{\overset{4}{\cancel{32}}}{8}\right) + 2240\right] \frac{kcal}{kg}$$

$$= \frac{556040}{100} \qquad \boxed{HCV = 5560.4 \ \frac{kcal}{kg}}$$

$$LCV = \left[HCV - \frac{9}{100} \times H \times 587\right]$$

$$= 5560.4 - \frac{9 \times 6 \times 587}{100} = 5560.4 - 316.98$$

$$\boxed{LCV = 5243.42 \ \frac{kcal}{kg}}$$

(8) Calculate GCV and NCV of coal Having following Compositions C = 80%, H = 6%, O = 8%, S = 1.5%, N = 2.1% and ash = 2.4%.

$$\Rightarrow \quad HCV = \frac{1}{100}\left[8080 \times C + 34500\left(H - \frac{O}{8}\right) + 2240 \times S\right] \frac{kcal}{kg}$$

$= \frac{1}{100}\left[8080 \times 80 + 34500\left(6 - \frac{8}{8}\right) + 2240 \times 1.5\right]$

$= \frac{646400 + 172500 + 3360}{100}$

$= \frac{822260}{100}$

$\boxed{HCV = 8222.60 \ \frac{kcal}{kg}}$

$LCV = 8222.60 - \frac{9 \times 6 \times 587}{100}$

$= 8222.60 - 316.98$

$\boxed{LCV = 7905.62 \ \frac{kcal}{kg}}$

(a) A coal having following composition by weight C = 75% O = 5% S = 2% If Net calorific value of coal was found to be 7200 kcal/g then calculate percentage of Hydrogen and Higher calorific value of coal

$\Rightarrow$

$HCV = \frac{1}{100}\left[8080 \times C + 34500\left(H - \frac{O}{8}\right) + 2240 \times S\right]$

$HCV = \frac{1}{100}\left[8080 \times 75 + 34500 H - 34500 \times \frac{5}{8} + 2240 \times 2\right]$

$= \frac{1}{100}\left[606000 + 34500H - 21562.5 + 4480\right]$

$HCV = \frac{588917.5}{100} + \frac{34500 H}{100}$

$\boxed{HCV = 5889.17 + 345H} \ \frac{kcal}{kg}$ -- (1)

$LCV = HCV - \frac{9 \times H \times 587}{100}$

$= 5889.17 + 345H - \frac{9}{100} \times 587 \times H$

$7200 = 5889.17 + (345 - 52.83)H$

$= 5889.17 + 292.17H$

$H = \frac{7200 - 5889.17}{292.17}$

$H = \frac{1310.83}{292.17}$

(H) put in eq(1)

$\boxed{H = 4.48\%}$

$HCV = 5889.17 + 345 \times 4.48$

$= 1547.85 + 5889.17$

$\boxed{HCV = 7434.77 \ kcal/kg}$

- moisture %
- Volatile %
- Ash %
- Fixed carbon %

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Proximate analysis and Numerical on it

(I) proximate analysis : proximate analysis is the study of analysis of coal in which moisture %, Volatile matter %, Ash %, fixed carbon % are estimated for engineering purpose

quality check

(1) Determination of moisture :

A known weight powdered (1) powdered and (2) air dried coal sample is taken in a crucible → Pot

{Initially weighted, Say (m) gram}

↓

It is placed in preheated oven For $\boxed{1 \text{ hour}}$ at 105° – 110°C

↓

Then after taking out from the oven

↓

it's cooled out in a desiccator

↓

finally weighed out (m_1 gm)

↓

Then the loss of weight ($m - m_1$) coressponding to moisture content in coal

$$\% \text{ Moisture content} = \frac{\text{Loss } \cancel{\text{in}} \text{ weight at } 105° - 110°C}{\text{weight of air dried coal}} \times 100$$

OR

$$\boxed{\% \text{ moisture content} = \frac{(\text{Initial weight}(m) - \text{Final weight}(m_1))}{\text{Initial weight}(m)} \times 100}$$

$$= \left(\frac{w - w_1}{w}\right) \times 100 \quad \text{or} \quad \left(\frac{m - m_1}{m}\right) \times 100$$

Significance: – (1) more moisture content → reduces → the calorific value as it does not burn

does not take away heat in the form of latent heat

It increases the ignition temperature of coal

– Hence, coal with (2) lesser moisture content is of better quality

(2) **Determination of volatile matter**:

moisture free coal left in the crucible 1st experiment (m_1 gm) is covered with lid loosely.

↓

Then it is heated at 925 ± 20°C in a muffle furnace for 7 min

↓

Then crucible is taken out

↓

cooled in a dessiccator

↓

then weighted again (m_2 gm)

↓

The loss in weight ($m_1 - m_2$)

↓

is due to loss of volatile matter in the (m) gm of coal sample

$$\% \text{ volatile matter} = \frac{\text{weight of volatile matter}}{\text{weight of air dried coal}} \times 100$$

$$\% \text{ volatile matter} = \frac{(m_1 - m_2)}{m} \times 100$$

decrease flame temperature ↓

Significance :- more volatile matter content → It decrease the calorific value of fuel

It form smoke and pollute air

- lesser is the volatile matter, → better is the quality of coal

(3) **Determination of ash** :

The coal left in above experiments

↓

Heated and burnt in a open crucible at 700° - 750°C for $\frac{1}{2}$ an hour

↓

In muffle furnace till a constant weight is obtained

↓

Cooled in a dessiccator

↓

weighted (m_3 gm)

$$\% \text{ Ash} = \frac{\text{weight of Ash}}{\text{weight of air dried coal}} \times 100$$

$$\% \text{ Ash} = \frac{m_3}{m} \times 100$$

Significance : its reduce the calorific value of fuel

(4) Determination of fixed carbon :

4 % of fixed carbon = 100 − (% moisture + % volatile matter + % ash)

Significance :

- Coal with Higher percentage of fixed Carbon → has greater calorific value

→ helps in design of furnance and shape of fire box

- Hence a good quality coal should have → High fixed carbon %

Summary

$$\% \text{ of moisture} = \frac{(W - W_1)\times 100}{W}$$

W → Hot air oven for 1 hour, 105 − 110°c → W_1

$$\% \text{ of volatile matter} = \frac{(W_1 - W_2)\times 100}{W}$$

W_1 → muffle furnace (covered with lid) For 7 min, 927 ± 20°c → W_2

$$\% \text{ of Ash} = \frac{W_3}{W}\times 100$$

W_2 → muffle furnance (without lid) For $\frac{1}{2}$ hour, 700 ± 50°c → W_3

% of fixed carbon = 100 − (% moisture + % volatile matter + % ash)

Numerical :

(1) Exactly 2.5g was weighted into silica crucible. After heating for 1 hour at 110°c the residue weighted 2.415g, the crucible next covered with a vented lid and strongly heated for exactly seven minutes at 950 ± 20°c. The residue weighted 1.528g. The crucible was then heated without cover at 700°c until a constant weight was obtained. The last residue was found to weight 0.245g. Calculate the percentage result of above analysis

=> weight of coal Taken = 2.5g (W)

weight of coal after heating at 110°c = 2.415g (W_1)

weight of coal after heating 950°c = 1.528g (W_2)

weight of coal after heating 700°c = 0.245g (W_3)

(i) % moisture content = $\frac{\text{loss of weight at } 105° - 110°c}{\text{weight of air dried coal}} \times 100$

$= \left(\frac{W - W_1}{W}\right) \times 100$

$= \frac{(2.5 - 2.415)}{2.5} \times 100$

$= \frac{0.085}{2.5} \times 100$

$\boxed{\text{\% moisture content} = 3.4\ \%}$

(2) % Volatile matter content $= \frac{(w_1 - w_2)}{w} \times 100$

$= \frac{(2.415 - 1.528)}{2.5} \times 100$

$\boxed{\%\ \text{Volatile mater} = 35.48\%}$

(3) % Ash content $= \frac{w_3}{w} \times 100$

$= \frac{0.245}{2.5} \times 100$

$= \frac{24.5}{2.5}$

$\boxed{\%\ \text{Ash content} = 9.8\ \%}$

(4) % fixed carbon = 100 − (% moisture + % Volatile matter + % Ash)

= 100 − (3.4 + 35.48 + 9.8

= 51.32 %

(3) one gram of air dried sample of coal on heating at 110°c for one hour produced a residue 0.85 gm and this residue on heating at 950°c for 7 min in absence of air left 0.72 gm mass which on combustion left 0.1 gm of non-combustile matter. Calculate the result of proximate analysis.

Sol.

(1) weight of coal taken = 1 gm (ω)

(2) weight of coal after heating at 110°c = 0.85 gm (ω_1)

(3) weight of coal after heating at 950°c = 0.72 gm (ω_2)

(4) weight of coal after heating at 700°c = 0.1 gm (ω_3)

(1) % moisture content = $\dfrac{\text{loss of weight at } 105°c - 110°c}{\text{weight of air dried coal}} \times 100$

$= \left(\dfrac{\omega - \omega_1}{\omega}\right) \times 100$

$= \left(\dfrac{1 - 0.85}{1}\right) = 0.15 \times 100$

$= 15\%$

(2) % volatile matter content $= \dfrac{(\omega_1 - \omega_2)}{\omega} \times 100$

$= \dfrac{(0.85 - 0.72)}{1} \times 100$

$= 0.13 \times 100$

$= 13\%$

(3) % Ash $= \dfrac{\omega_3}{\omega} \times 100 = \dfrac{0.1}{1} \times 100$

$= 10\%$

(4) % Fixed carbon $= 100 - (15 + 13 + 10)$

$= 100 - 38$

$= 62\%$

(4) An air dried sample of coal weighing 2.9 gm was taken for volatile matter determination after loosing matter the coal sample weighed 1.96 gm. If it contains 4.5 % moisture find percentage of volatile matter in it.

Sol.

(1) weight of coal taken = 2.9 gm

(2) % of moisture = 4.5 %

(3) weight of coal after removal moisture = 1.96 gm (W_2)

(1) % moisture = $\frac{\text{loss of weight at } 105°c - 110°c}{\text{weight of air dried coal}} \times 100$

$$45\% = \frac{(2.9) - W_1}{2.9} \times 100$$

$$\frac{45 \times 2.9}{100} = 2.9 - W_1$$

$$W_1 = 2.9 - \frac{45 \times 2.9}{100}$$

$$W_1 = 2.9 - 0.1305$$

$$\boxed{W_1 = 2.7695 \text{ gm}}$$

(2) % Volatile matter Content = $\frac{(W_1 - W_2) \times 100}{W}$

$$= \left(\frac{2.7695 - 1.96}{2.9}\right) \times 100 = \frac{0.8095}{2.9} \times 100$$

$$= 0.2798 \times 100$$

$$= 27.98\ \%$$

Q7) 2.0 gram of air dried coal on heating for 1 hour at 110°C the residue weighted 1.75 gm, the crucible next covered with a vented lid and strongly heated for exactly 7 minutes at 950 ± 20 °C. The residue weighted 1.45 gm. The residue on further combustion left 0.3 gm of non-combustible matter. Calculate the result of proximate analysis.

Sol. % mois. = 12.5%, % V.M = 15%, % Ash = 15%

% fixed C = 58.5%

(i) Weight of coal take = 2 gm (W)

(ii) weight of coal After 110°C = 1.75 gm (W_1)

(iii) weight of coal After 950°C = 1.45 gm (W_2)

(iv) weight of coal After heating 700°C = 0.3 gm (W_3)

$$\%\ \text{moisture} = \frac{\text{loss of weight at } 105° \text{ to } 115°C}{\text{weight air dried coal}} \times 100$$

$$= \left(\frac{W - W_1}{W}\right) \times 100 = \frac{(2 - 1.75)}{2} \times 100$$

$$= \frac{0.25 \times 100}{2}$$

$$= 12.5\%$$

$$\%\ \text{volatile matter} = \frac{(W_1 - W_2)}{W} \times 100 = \frac{(1.75 - 1.45) \times 100}{2}$$

$$= \frac{30}{2} = 15\%$$

$$\%\ \text{Ash} = \frac{W_3}{W} \times 100 = \frac{0.3 \times 100}{2} = \frac{30}{2} = 15\%$$

$$\%\ \text{Fixed Carbon} = 100 - (\%\ \text{moisture} + \%\ \text{volatile matter} + \%\ \text{Ash})$$

$$= 100 - (15 + 15 + 12.5)$$

$$= 100 - (42.5) = 57.5\%$$

(1) Carbon and hydrogen %
(2) Nitrogen %
(3) Sulphur %
(4) Ash %

(II) Ultimate analysis : → It is useful in classification of coal

→ In combustion calculations as it determines the % of
- High Carbon
- hydrogen
- low nitrogen →
- low sulphur →
- low oxygen →
- low ash →

Signification

Combus

(1) Determination of Carbon and hydrogen :

- A known weight of air dried coal is taken in porcelain boat and is burnt.

- Carbon (C) → converted into → carbon dioxide (CO_2) {absorbed by KOH tube}

- Hydrogen (H) → converted into → water (H_2O) {absorbed by anhydrous of $CaCl_2$}

let (1) the weight of coal = W gm
(2) weight of H_2O = a gm
(3) weight of CO_2 = b gm

O_2 ko known volume of KOH ke sath absorbed kara denge
→ KOH + CO_2 → K_2CO_3

For carbon :

$C + O_2 \rightarrow CO_2$

12 gm C → 44 g CO_2

$2KOH + CO_2 \rightarrow K_2CO_3 + H_2O$

increase weight find and → we get amount O_2

① suppose increases in weight of KOH tube due to CO_2 absorption is x g

44 gm CO_2 contains 12 gm carbon

② x g indicates amount of CO_2 produce by carbon in coal sample

b gm CO_2 contains $\frac{12 \times b}{44}$ gm carbon

W gm of CO_2 contain $\frac{12 \times b}{44 \times W}$ gm C.

suppose weight of coal sample is W g

100 gm coal will contain $\frac{12 \times b \times 100}{44 \times W}$ gm carbon

↳ for %

= % Carbon in coal

$$\boxed{C\% = \frac{12}{44} \cdot \frac{\text{weight of } CO_2 \text{ formed}}{\text{weight of coal sample}} \times 100}$$

① Suppose increase weight of anhydrous $CaCl_2$ tube due to H_2O absorption y gm

H_2O is absorbed by anhydrous $CaCl_2$

$CaCl_2 + 7H_2O \rightarrow CaCl_2 \cdot 7H_2O$

Increase in weight find out, we get amount of H_2O

For Hydrogen :

$2H_2 + O_2 \longrightarrow 2H_2O$

② y gm indicate the amount of H_2O produce by hydrogen in coal sample

4 gm $H_2 \longrightarrow 36$ gm of H_2O

$CaCl_2 + 7H_2O \longrightarrow CaCl_2 \cdot 7H_2O$

36 gm of H_2O contain 4 gm of H_2

a gm of H_2O contain $\frac{4}{36} \times a$ gm of H_2

W gm of H_2O contain $\frac{4}{36} \times \frac{a}{W}$ gm of H_2

100 gm of H_2O contain $\frac{4}{36} \times a \times 100$ gm of H_2

Suppose weight of coal sample is W g

$= \%$ Hydrogen in coal

Combustion Apparatus

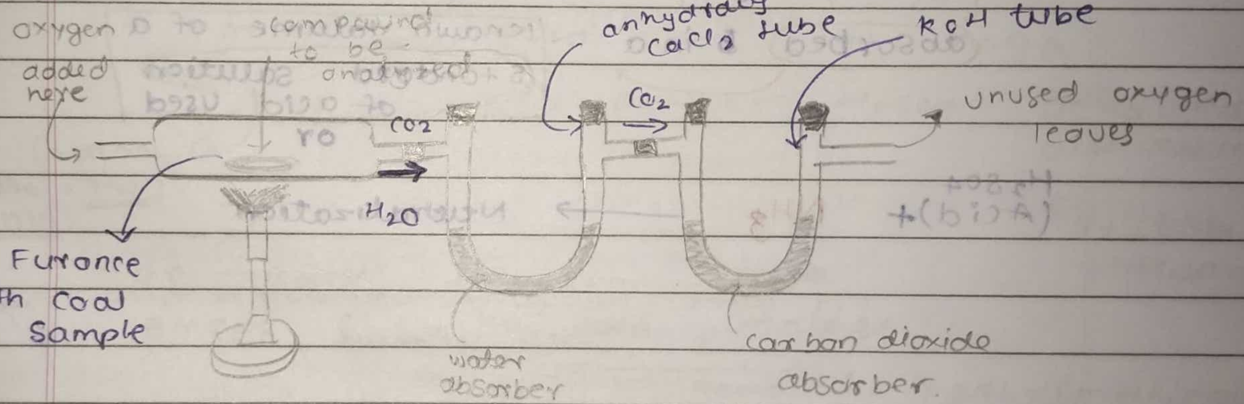
Kjeldahl's method

Bomb Calorimeter

By Subtraction Calculation

By Proximate analysis

$$\boxed{H\% = \frac{4}{36} \, \frac{\text{weight of } H_2O \text{ formed} \times 100}{\text{weight of coal sample}}}$$



Combustion Apparatus

Significance :

① – Higher is the % of carbon → Higher is the calorific value

③ – Hydrogen present along with oxygen which is not desirable

② – lesser is the % of Hydrogen → better is the quality of coal.

(2) Determination of nitrogen :

- Nitrogen present in coal sample can be estimated by Kjeldahl's method.

$$N + \underset{\text{conc.}}{\overset{20ml}{H_2SO_4}} \xrightarrow[K_2SO_4]{Heat} (NH_4)_2SO_4 \text{ (ammonium sulphate)}$$

10 gm

$(NH_4)_2SO_4$

- The contents are then transferred to a round bottomed flask

- Solution is heated with excess of NaOH

KOH also present

$$(NH_4)_2SO_4 + \underset{(excess)}{NaOH} \longrightarrow 2NH_3 + Na_2SO_4 + 2H_2O$$

- The ammonia gas thus liberated is absorbed in a known volume of a standard solution of acid used

or

known conc. and volume

H_2SO_4 (Acid) + NH_3 $\longrightarrow$ Neutralization

Kitne equivalent ammonia (NH_3) ne kitne (H_2SO_4) used kiya hai

- then further convert in ammonium sulphate

usko help se hum Nitrogen calculate karenge

$$H_2SO_4 + NH_3 \longrightarrow (NH_4)_2SO_4$$

- Unused acid is determined by back titration with std NaOH solution

Normality is $\frac{N}{10}$

assume 50ml of H_2SO_4

pass NH_3

40 ml of H_2SO_4 are unused acid

10ml of H_2SO_4 + NH_3 → Neutralized

Initial unused acid

50 - 40 ⇒ 10ml remaining Pata chala

10ml H_2SO_4 ne ammonia neutralized kiya hai

then (H_2SO_4) Acid → Back titration

Std. NaOH → N normality $\frac{N}{10}$

10 ml → yeah wala amant find karna hota hai jiska ammonia ne neutralized kiya hai

→ hume Nitrogen % find karna hai

to Fir hume acid ke sath NH_3 ko react karenge
↳ use hume patha kar na hai
ek kitna amant NH_3 reaction with H_2SO_4 $\xrightarrow{\text{convert}}$ Neutralization

~~to hume path kar~~ hai NH_3 ke kitna amant used kiya H_2SO_4 ke Neutralization hoke liya

par H_2SO_4 pura used nhi hoga
jitna remaing part of H_2SO_4 usko find out karke
↳ By Back titration

or Back titration jitna amant H_2SO_4 ka ~~pata~~ chalege usko remain/unused find kar lege

to hume pata chaleg ke kitna H_2SO_4 ke kitna ammonia neutralized hua

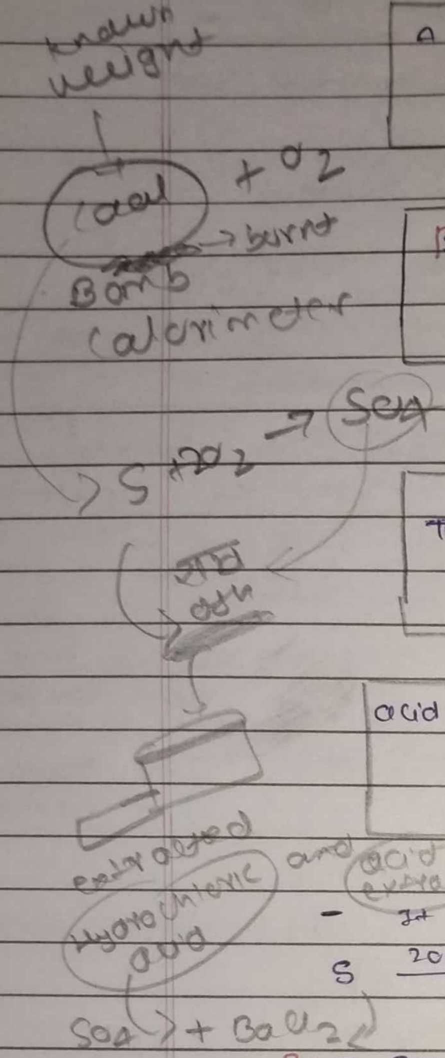
let the weight of coal sample taken = x
Normality of H_2SO_4 = N
Valume of H_2SO_4 used = V

Normality same

$$\boxed{\% \text{ of } N = \frac{\text{valume of acid used} \times \text{Normality of acid used}}{\text{weight of coal taken}} \times 1.4}$$

$$= \frac{V \times N \times 14 \times 100}{1000 \times W} = \frac{V \times N}{W} \times 1.4$$

(3) Determination of sulphur :



A known weight of Coal is burnt in a bomb Calorimeter in presence of oxygen

↓

Sulphur present combines with oxygen and get Converted into sulphate

↓

$$S \xrightarrow{2O_2} SO_4$$

The ash formed is extrated with dill Hydrochloric acid and acid extract

↓

acid extract is heated with barium Chloride solution to given white ppt of barium sulphate

$$SO_4 \xrightarrow{BaCl_2} BaSO_4$$

- It is filtered, washed, dried and weight

$$S \xrightarrow{2O_2} SO_4 \xrightarrow{BaCl_2} BaSO_4$$

32g sulphur given 233 gm $BaSO_4$

{ let wt of coal taken = W
wt. of $BaSO_4$ formed = xg }

233 g of $BaSO_4$ contains 32 g of S

x g of $BaSO_4$ contain $\frac{32}{233} \times (x)$ g of sulphur

W g of coal contain $\frac{32(x)}{233 \times W}$ g of S

100g of coal contain $\frac{32x \times 100}{233 \times w}$

$$\boxed{\% \text{ of S in coal} = \frac{32}{233} \times \frac{\text{weight of } BaSO_4}{\text{weight of coal}} \times 100}$$

(4) **Determination of oxygen** :

It determined by substraction. addition of % carbon, Nitrogen, Hydrogen, sulphur, Ash from 100

$$\boxed{\% O = 100 - (C\% + H\% + N\% + S\% + ash\%)}$$

Significance :

lesser the % of oxygen → less will be moisture content

lesser the % of oxygen → High calorific value

It is said that

↑ Increase in 1% oxygen ⟶ ↓ decrease the calorific value of coal by 1.7%

(5) **Determination of Ash** :

As discussed in proximate analysis

Carbon or
Hydrogen

KOH

Numerical

(1) 0.2 gm of coal sample is accurately weighted and is burnt in a combustion apparatus. The gaseous products of combustion are absorbed in potash bulb (KOH) and calcium chloride ($CaCl_2$) tubes of know weight. The increase in weight of potash bulb and $CaCl_2$ tubes are 0.66 gm of 0.08 gm respect... Calculate the % of carbon and (H) in the coal sample

=>

weight of coal is 0.2 gm

weight of CO_2 = 0.66 gm

~~weight of H_2O = 0.08 gm~~

$$\% \text{ of Carbon} = \frac{12}{44} \times \frac{\text{weight of } CO_2}{\text{weight of coal sample}} \times 100$$

$$= \frac{\cancel{12}^{6}}{44} \times \frac{0.66}{0.\cancel{2}} \times 100$$

$$= \frac{33\cancel{8}}{\cancel{4.4}} = 90\%$$

$$\boxed{\% \text{ of Carbon} = 90\%}$$

$$\% \text{ of Hydrogen} = \frac{\cancel{2}}{18} \times \frac{\text{weight of } H_2O}{\text{weight of coal sample}} \times 100$$

$$= \frac{0.08 \times 100}{9 \times 0.2}$$

$$= \frac{\cancel{8}^{4} \times 10}{9 \times \cancel{2}} = \frac{40}{9}$$

$$\boxed{\% \text{ of Hydrogen} = 4.44\%}$$

Carbon and hydrogen

(2) 1.5 gm of coal simple is accurately weighed and is burnt in a combustion apparatus. The gaseous products of combustion are absorbed in potash bulb and calcium chloride tubes of known weight. The increase in weight of potash bulb and $CaCl_2$ tubes are 4.88 gm and 1.25 gm respectively. calculate the percentage of carbon and hydrogen in the coal sample

weight of coal sample = 1.5 gm
⇒ weight of CO_2 = 4.88 gm
weight of H_2O = 1.25 gm

$$\% \text{ of carbon} = \frac{12}{44} \times \frac{\text{weight of } CO_2}{\text{weight of coal sample}} \times 100$$

$$= \frac{12}{44} \times \frac{4.88}{1.5} \times 100$$

$$= \frac{12 \times 4.88 \times 100}{66} = \underline{88.7\%}$$

$$\% \text{ of Hydrogen} = \frac{2}{18} \times \frac{\text{weight of } H_2O}{\text{weight of coal sample}} \times 100$$

$$= \frac{2}{18} \times \frac{1.25}{1.5} \times 100 = \frac{250}{27}$$

$$= \cancel{\frac{125}{13.5}} = \cancel{\times A} \qquad = \underline{9.25\%}$$

Nitrogen and Sulphur

(3) 1.95 gm of coal sample was taken for nitrogen estimation by Kjeldahl method. The ammonia liberated required 9.5 ml of 0.4 N H_2SO_4 for neutralization. The same sample of coal weighing 1.5 gm in a Bombs calorimeter experiment produced 0.35 gm of $BaSO_4$. Calculate the % of N and S.

⟹ weight of coal sample = 1.95 gm

volume of acid used = 9.5 ml

Normality of acid = 0.4

% of nitrogen = $\frac{\text{Volume of acid used} \times \text{Normality} \times 1.4}{\text{weight of coal sample}}$

$= \frac{9.5 \times 0.4 \times 1.4}{1.95} = \frac{5.32}{1.95}$

$\boxed{\text{\% of nitrogen} = 2.728\ \%}$

weight of coal semple is 1.5 gm

% of Sulphur = $\frac{33}{233} \times \frac{\text{weight of } BaSO_4}{\text{weight of coal sample}} \times 100$

$= \frac{33}{233} \times \frac{0.35 \times 100}{1.5} = \frac{1155}{\cancel{454.35}\ 349.5}$

$\boxed{\text{\% of sulphur} = 3.3042\ \%}$

N and S $\quad N \rightarrow NH_3 \rightarrow H_2SO_4 \rightarrow$ $\boxed{Base}$ $\quad V - V_1$

$V_1 \quad = 40 - 16$

Date
Page

(4) 3.2 gm of coal in kjeldahls experiment evolved ammonia which was absorbed in 40ml of 0.5N H_2SO_4. After absorption, the excess acid required 16ml of 0.5N KOH for complete neutralization 2.5gm of coal sample in quantitative analysis gave 0.42gm of $BaSO_4$ Calculate the % of N and S.

=> weight of coal sample = 3.2 gm

$$\% \text{ of Nitrogen} = \frac{\text{Volume of acid used} \times \text{Normality of acid used} \times 1.4}{\text{weight of Coal sample}}$$

$$= \frac{(40-16) \times 0.5 \times 1.4}{3.2}$$

$$= \frac{16.8}{3.2} = 5.25\,\%$$

weight of coal sampe = 2.5 gm

$$\% \text{ of sulphur} = \frac{32}{233} \frac{\text{weight of } BaSO_4 \times 100}{\text{weight of coal sample}}$$

$$= \frac{32}{233} \times \frac{0.42 \times 100}{2.5}$$

$$= \frac{42 \times 32}{582.5} = \frac{1344}{582.5}$$

$$\boxed{\% \text{ of S} = 2.307\,\%}$$

Note: % of O_2 in air by weight = 23%
% of O_2 in air by volume = 21%

Calculation quantity of air required for combustion of fuel:

By $\boxed{\text{weight}}$ and $\boxed{\text{volume}}$

(1) ① O_2 Quantity $= \left[\frac{32}{12} C + 8\left(H - \frac{O}{8}\right) + S\right]$

(2) ② Quantity of air = Oxygen quantity $\times \frac{100}{23}$ kg

(3) Volume of air = Volume of air $\times \frac{100}{21}$ m^3

Volume of O_2 = $\frac{\text{Quantity of } O_2}{32} \times 22.4$

OR

③ Volume of air required = $\frac{\text{wt. of air required}}{28.94} \times 22.4$

28.94 → molecular wt of air

28.94 kg of O_2 ⟶ 22.4 m^3

$C + O_2 \longrightarrow CO_2$
12 32 44

$S + O_2 \longrightarrow SO_2$
32 32 64

Numerical

(1) Calculate the weight of air needed for complete combustion of 5 kg of coal having following composition C = 86 %, H = 5 %, S = 2.5 %, N = 1.5 % remaining is ash

Sol:

This all are combustible

Constituent	% by wt	wt. of each per kg of
C	86	$\frac{86}{100}$ 0.86
H	5	$\frac{5}{100}$ 0.05
S	2.5	$\frac{2.5}{100}$ 0.025

$\frac{32}{32} S = 1S$

$$\text{Quatity of } O_2 = \left[\frac{32}{12} C + 8\left(H - \frac{O}{8}\right) + S\right]$$

$$= \left(\frac{32}{12} \times 0.86 + 8\left(0.05 - \frac{(0)}{8}\right) + 0.025\right)$$

zero

$$= \left(2.29 + 0.4 - \frac{8(0)}{8} + 0.025\right)$$

$$= (2.29 + 0.4 + 0.025)$$

$$= \cancel{5.19}\ 2.715$$

$$\text{Air} = \frac{100}{23} \times \text{Quantity of air}$$

$$= \frac{100}{23} \times 2.715 = \frac{271.5}{23}$$

$$= 11.83 \text{ kg}$$

Therefore,

for 5kg $= 11.83 \times 5$

$= 59.12$ kg

28.949 kg of air $\longrightarrow$ 22.4 m^3

1 kg of air $= \frac{22.4}{28.949}$ m^3

$\boxed{10.9 \text{ kg of air} = \frac{10.9 \times 22.4}{28.94} m^3}$

$= 8.4367$

(2) The % analysis of coal contains 8.5% carbon, 5% Hydrogen, 1% Sulphur, 1% Oxygen and 8% ash. Calculate the theoretical weight and volume at (N.T.P) of air required for complete combustion of 4kg of coal sample

Sol.

Constituent	by weight %	wt of each per kg of
C	8.5	$\frac{8.5}{100} = 0.085$
H	5	$\frac{5}{100} = 0.05$
S	1	$\frac{1}{100} = 0.01$
O	1	$\frac{1}{100} = 0.01$

$$\text{Air} = \frac{100}{23} \times \text{Quantity of } O_2$$

$$= \frac{100}{23} \times \left[\frac{32}{12} \times C + 8\left(H - \frac{O}{8}\right) + S\right]$$

$$= \frac{100}{23}\left[\frac{32}{12} \times 0.085 + 8\left(0.05 - \frac{0.01}{8}\right) + 0.01\right]$$

$$= \frac{100}{23}\left[\frac{2.72}{12} + 0.4 - \cancel{0.01} + \cancel{0.01}\right]$$

$$= \frac{100}{23}\left[0.226 + 0.4\right] = \frac{100}{23} \times 0.626$$

$$= \frac{62.6}{23}$$

Air = 2.721 kg

therefore, for 4kg = 2.721×4

= 10.9 kg

OR

$$\text{Volume of } O_2 = \frac{\text{wt of air required}}{28.94} \times 22.4 \ m^3$$

$$= \frac{10.9 \times 22.4}{28.94}$$

$$= 8.4367 \ m^3$$

(3) A coal sample has the following composition by weight C = 84 %, H = 6 %, S = 1 %, O = 8 % and remaining ash. Calculate the minimum quantity of air required both by weight and volume for complete combustion of 2kg of this fuel

=>

Constituent	by weight %	weight of each per kg of
C	84%	0.84
H	6%	0.06
S	1	0.01
O	8 %	0.08

~~Wate~~ Quantity of Air = $\frac{100}{23}$ Quantity of O_2

$$= \frac{100}{23}\left[\frac{32}{12}\times C + 8\left(H - \frac{O}{8}\right) + S\right]$$

$$= \frac{100}{23}\left[\frac{32}{12}\times 0.84 + 8\left(0.06 - \frac{0.08}{8}\right) + 0.01\right]$$

$$= \frac{100}{23}\left[2.24 + 0.48 - 0.08 + 0.01\right.$$

$\cancel{0.07}$

$$= \frac{100}{23}\left[2.24 + 0.41\right] = \frac{100}{23}\times 2.65$$

$$= 11.5217 \text{ kg}$$

for 2kg $= 11.5217 \times 2$

$= 23$ kg

28.94 kg of O_2 → 22.4 m^3

1 kg of O_2 → $\frac{22.4}{28.94}$ m^3

23 kg of O_2 → $\frac{22.4\times 23}{28.94}$ m^3

Volume of Air = 17.80 m^3 = 17.8 litre//

Date ______
Page ______

(Q4) A coal sample has the following composition by weight C=75%, H=12%, S=4%, O=6% and remaining ash. Calculate the minimum quantity of air required both by weight and volume for complete combustion of 5kg of this fuel

sol.

constituent	% by weight	weight of each per kg of
C	75	0.75
H	12	0.12
S	4	0.04
O	6	0.06

quantity of air = volume of $O_2 \times \frac{100}{23}$

$$= \frac{100}{23}\left[\frac{32}{12} \times C + 8\left(H - \frac{O}{8}\right) + S\right]$$

$$= \frac{100}{23}\left[\frac{32}{12} \times 0.75 + 8\left(0.12 - \frac{0.06}{8}\right) + 0.04\right]$$

$$= \frac{100}{23}\left[2 + 0.96 - 0.06 + 0.04\right]$$

$$= \frac{100}{23}\left[2 + 0.94\right]$$

$$= \frac{2.94 \times 100}{23}$$

$$= 12.78 \text{ kg}$$

For 5kg $= 12.78 \times 5$

$= \underline{63.91 \text{ kg}}$

28.94 kg of $O_2 \longrightarrow 22.4 \ m^3$

1kg of $O_2 \longrightarrow \frac{22.4}{28.94} \ m^3$

63.91kg of $O_2 \longrightarrow \frac{22.4}{28.94} \times 63.91 \times m^3$

volume of air $=$ $\underline{49.46 \text{ litre}}$

valume

(6) A gas has the following composition by volume $CO = 10\%$, $CH_4 = 30\%$, $H_2 = 40\%$, $N_2 = 3\%$, $CO_2 = 3\%$, $O_2 = 2\%$, $C_3H_8 = 12\%$. Find the volume and weight of air actually supplied per m^3 of this gas

$\Rightarrow$

constituent	% by wt	wt. of each per kg of
CO	10	0.1
CH_4	30	0.3
H_2	40	0.4
C_3H_8	12	0.12
O_2	3	0.03
CO_2 and N_2	No reaction	

$$CO + \frac{1}{2}O_2 \longrightarrow CO_2$$

1 volume of CO $\longrightarrow$ 0.5 volume of O_2

0.1 volume of CO $\longrightarrow$ 0.5×0.1 volume of O_2

$\longrightarrow$ 0.05 volume of O_2

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

1 volume of CH_4 $\longrightarrow$ 2 volume of O_2

0.3 volume of CH_4 $\longrightarrow$ 2×0.3 volume of O_2

$\longrightarrow$ 0.6 volume of O_2

$$H_2 + \frac{1}{2}O_2 \longrightarrow H_2O$$

1 volume of H_2 $\longrightarrow$ 0.5 volume of O_2

0.4 volume of H_2 $\longrightarrow$ 0.5×0.4 volume of O_2

$\longrightarrow$ 0.2 volume of O_2

$$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$$

1 volume of C_3H_8 $\longrightarrow$ 5 volume of O_2

0.12 volume of C_3H_8 $\longrightarrow$ 5×0.12 volume of O_2

0.6 volume of O_2

Total volume of O_2 = $0.05 + 0.6 + 0.2 + 0.6$

$= 1.45\ m^3$

O_2 available in fuel $= 0.03$

O_2 needed $= 1.45 - 0.03 = 1.42\ m^3$

$21\ m^3$ of $O_2 \longrightarrow 100\ m^3$ of air

$1.42\ m^3$ of $O_2 \longrightarrow \frac{100 \times 1.42}{21} \times m^3$ of air

$\Rightarrow 6.7619\ m^3$ of air

$\boxed{\text{Volume of air} = 6.7619\ m^3}$

we know that

$1 m^3 = \frac{28.94}{\cancel{28.9}\ 22.4}$ kg

$6.7619\ m^3 = \frac{28.94}{22.4} \times 6.7619$ - kg

$\boxed{\text{weight } \cancel{\text{volume}} \text{ of air} = 8.736\ kg}$

power alcohol :-

- when ethyl alcohol is used as a Fuel it is called as power alcohol

Generally, ethyl alcohol is used 5 - 25 % mixture in petrol

Industrical alcohol can also be blended with the help of blending agent

Advantage :-

- Power alcohol is cheaper than petrol
- Ethanol is a good antknocking property and
- its Octane no is 90 (petrol) 65.

disadvantage :-

- Ethyl alcohol may undergoes oxidation to form acetic acid which corrodes engine part
- Calorific value of petrol is lowered because of alcohol

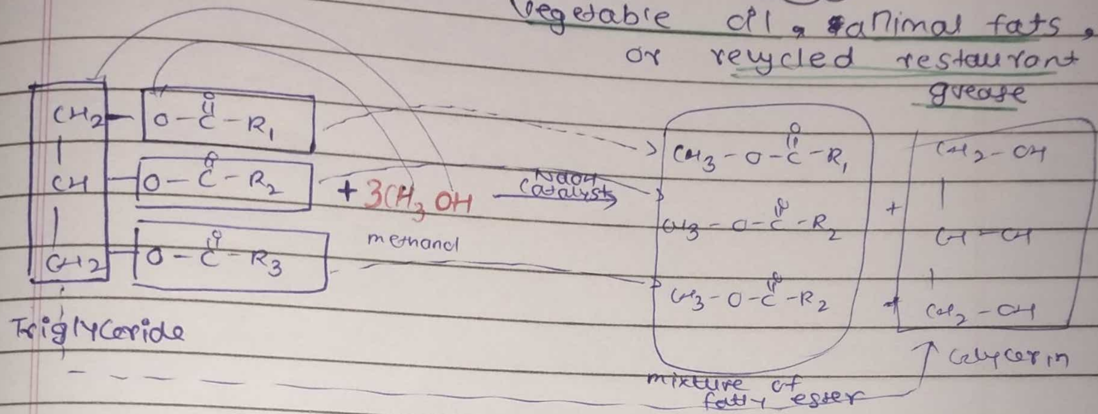
→ Bio-desel is produced transesterification of the vegetable oil

Bio-desel

Bio-desel is renewable, biodegradable fuel

manufactured domestically from

vegetable oil, animal fats, or recycled restaurant grease



Bio desel synthesis of trasesterification

- process of converting one ester to another ester

Step to obtain biodiesel :-

(1) Filtration of vegetable oil
(2) Heating at 110°c → For remove of water
(3) Heating mixing for 30 min

advantages

(1) prepared renewable resource
(2) calorific value 40 kJ/gm
(3) octane No 40 to 50
(4) It is biodegradable and non-toxic
(5) It can be used as a Heating fuel For domestic and commerical purpose