

CHARACTERISTICS OF AN IDEAL FUEL

- (1) High calorific value
- (2) Low ignition temperature
- (3) Cheap, easy to transport
- (4) Less hazardous
- (5) Easy to store
- (6) Environment friendly
- (7) Ashless or less ash content

Analysis of Fuels (Coal)

The quality of coal can be determined by the following two types of analysis.

① Proximate Analysis

It is determination of moisture, volatile matter, ash content and fixed carbon. This analysis gives quick and valuable information about the quality of coal.

② Ultimate analysis

→ MOISTURE :-

About 1 gram of powdered coal taken in a crucible. Heat in an oven at 105-110°C for 1 hour. cool it and weigh.

$$\% \text{ of Moisture} = \frac{\text{loss in weight}}{\text{weight of coal taken}} \times 100$$

(2) Volatile matter:-

Coal from step(1) taken in a silica crucible (Covered). Place it in a muffle furnace for 7 min at 350°C. cool it and weigh.

$$\% \text{ of volatile matter} = \frac{\text{loss in weight}}{\text{weight of coal taken}} \times 100$$

By:

(3) Ash content :-

Coal from step (2). Heat it (uncovered) in a muffle furnace at 700 - 750°C for 30 minutes. cool it and weigh. Repeat the process until constant weight is obtained.

$$\% \text{ of ash content} = \frac{\text{wt. of ash left}}{\text{wt. of coal taken}} \times 100$$

(4) Fixed carbon:-

$$\% \text{ of C} = 100 - \% \text{ of (moisture + volatile matter + Ash content)}$$

Higher the % of fixed carbon, higher will be its calorific value

9
10°C

ULTIMATE ANALYSIS

It is the elemental analysis of coal in which % of carbon, hydrogen, nitrogen, oxygen and sulphur ^{and ash content} are determined.

(a) Carbon and Hydrogen

1 gram of coal sample is burnt in presence of Oxygen in a combustion apparatus. Carbon and hydrogen present in coal are converted into CO_2 and H_2O . These gaseous products are absorbed in KOH and CaCl_2 tubes of known weight. The increase in weights of these are determined.

Let x be increase in wt. of CaCl_2
 y = increase in wt. of KOH

then

$$\% \text{ of H} = \frac{2}{18} \times \frac{\text{Increase in wt. of } \text{CaCl}_2 \times 100}{\text{wt.}}$$

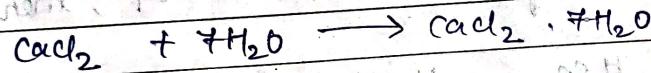
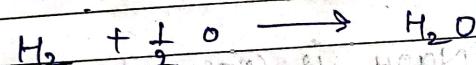
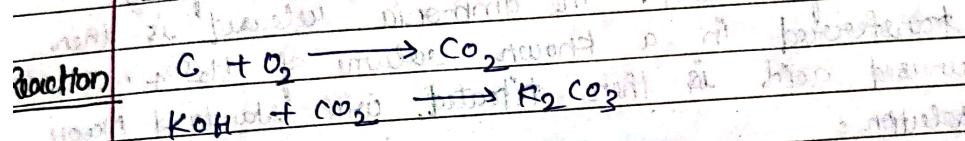
18g of H_2O contain 2g of H.

$$\frac{2}{18} \times \frac{\text{Increase in wt. of } \text{CaCl}_2 \times 100}{\text{wt.}} = \frac{2}{18} \times \frac{\text{Increase in wt. of } \text{KOH}}{\text{wt.}}$$

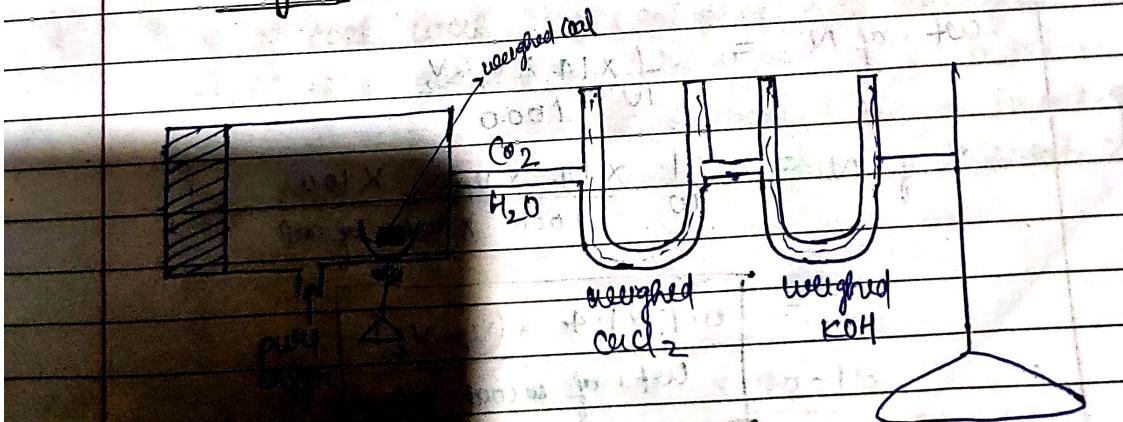
$$\% \text{ of H} = \frac{2}{18} \times \frac{\text{Increase in wt. of } \text{CaCl}_2 \times 100}{\text{wt. of coal}}$$

→ If 44g CO_2 contains 12g of C
 $1\text{g} \xrightarrow{\text{12}} \frac{12}{44} \text{ of C}$
 $\therefore y\text{ g of } \text{CO}_2 \xrightarrow{\text{12}} \frac{12}{44} \text{ of C}$

$80\% \text{ of C} = \frac{12}{44} \times \text{Increase in wt of KOH} \times 100$



Figure



(2) Nitrogen (Kjeldahl's method)

1 g coal is heated with concentrated H_2SO_4 in Kjeldahl's flask using $(CuSO_4 + K_2SO_4)$ as catalyst. Ammonium sulphate $(NH_4)_2SO_4$ is formed which is then transferred in ground bottom flask containing NaOH. The ammonia released is then transferred in a known volume of H_2SO_4 . The unused acid is then titrated with standard NaOH solution.

net V_2 ml of NaOH is consumed, then

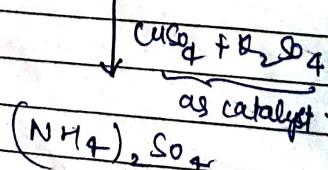
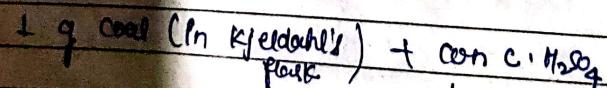
$$\text{amount of } H_2SO_4 = V_1 - V_2 \\ \text{neutralised by } NH_3$$

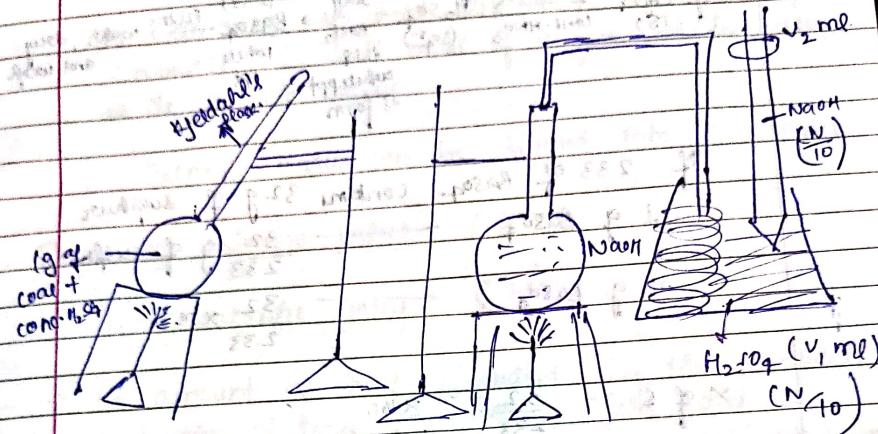
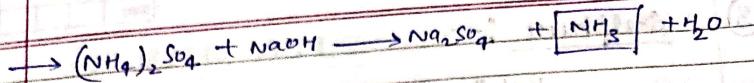
$$\text{wt. of N} = \frac{1 \times 14 \times (V_1 - V_2)}{10 \times 1000}$$

$$\% \text{ of N} = \frac{1 \times 14 \times (V_1 - V_2) \times 100}{10 \times 1000 \times \text{wt. of coal}}$$

$$= \frac{0.14 \times (V_1 - V_2)}{\text{wt. of coal taken}}$$

Reaction:



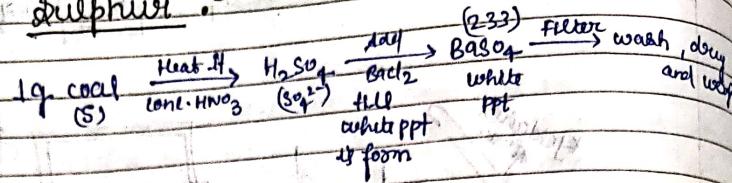


(Q) 3 g of coal was kilodisolved and NH_3 gas thus evolved thus absorbed by $1\text{m}\text{l}$ to 10ml of $\frac{N}{10}$ H_2SO_4 . After absorption, the excess acid required 10ml of $\frac{N}{10}$ NaOH for exact neutralisation. Calculate % of nitrogen in coal sample?

Sol: % of nitrogen = $\frac{0.1 \times 1.4}{3} \times 90 - 16$

$= 1.4\%$ Ans.

(3) sulphur :-



$$\begin{array}{l} \text{If 233 g of BaSO}_4 \text{ contains 32 g of sulphur} \\ 1\text{ g. BaSO}_4 \longrightarrow \frac{32}{233} \text{ g of sulphur} \\ n\text{ g. BaSO}_4 \longrightarrow \frac{32 \times n}{233} \end{array}$$

$$\% \text{ of S} = \frac{32 \times n \times 100}{233 \times \text{wt. of coal taken}}$$

$$\% \text{ of S} = \frac{32 \times \text{wt. of BaSO}_4 \times 100}{233 \times \text{wt. of coal taken}}$$

(4) ash content

It will be done by proximate analysis.

(5) Oxygen

$$O = 100 - \% \text{ of } (C + H + N + S + \text{Ash})$$

→ higher the % oxygen in coal, higher be its calorific value

CALORIFIC VALUE

The amount of heat liberated by the complete combustion of unit mass of a fuel is called its calorific value.

Calorific value can be divided into two types.

① Gross calorific value (G.C.V.)

or

High calorific value (H.C.V.)

→ The amount of heat liberated by the complete combustion of unit mass of a fuel and the products of combustion have been cooled at room temperature.

→ For ex → If the fuel contains Hydrogen it will get converted into steam on combustion but on cooling at room temperature, the steam changes into water.

Therefore latent heat of steam is also included with the measured heat.

② Net calorific value

or

Low calorific value

→ The amount of heat liberated by the complete combustion of unit mass of a fuel and the product on combustion are allowed to escape.

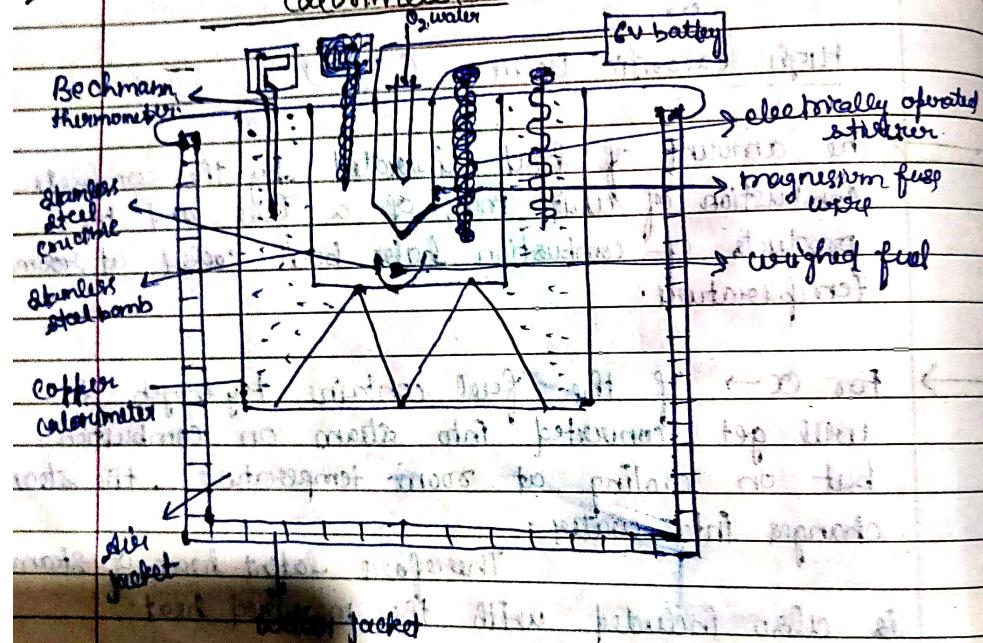
$$NCV = q \cdot C \cdot V - \text{Latent heat of steam}$$

$$\text{Latent heat of steam} = q \cdot C \cdot V \rightarrow \text{mass of Hydrogen} \times g \times \text{Latent heat of steam}$$

The Elec
circuit
place
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very important Determination of calorific value By Bomb calorimeter



A known amount of fuel is taken in crucible in stainless steel bomb. Magnesium fuse wire are attached with the fuel. The bomb is placed carefully in a copper calorimeter containing 1 kg of water. After allowing the initial temperature of water is noted.

The Electrodes are often connected with battery and circuit is completed. The combustion of fuel takes place and final temperature (of) water is again then noted.

Let X = Mass of fuel taken

w = weight of water taken in calorimeter

w = water equivalent of calorimeter, bomb, →
bomb, stirrer and thermometer.

L = A.C.V of fuel

t_1 = initial temperature of water

t_2 = Final temperature of water

→ ΔQ , Heat liberated by fuel = $X \cdot L$

→ Heat absorbed by water = $w \times s \times (t_2 - t_1)$

→ Heat absorbed by operator = $w \times s \times (t_2 - t_1)$

→ Total Heat liberated = $(w+w) (t_2 - t_1)$

As heat liberated = Heat absorbed

$$So X \cdot L = (w+w) (t_2 - t_1)$$

$$L = \frac{(w+w) (t_2 - t_1)}{X}$$

Corrections: = ~~Introducing heat loss due to insulation~~
~~Introducing air, heat loss due to insulation~~

Fuel water (C_f)

Cotton thread correction (C_{CT})

Acid correction (C_A)

Cooling correction (C_C)

$$L = (W + w) (t_0 + t_f - C_C) - (C_f + C_{CT} + C_A)$$

For more accurate results, following corrections must be considered during calculation of calorific value of a fuel.

(i) Fuel water correction (C_f)

The heat liberated due to combustion of fuel also includes the heat liberated by magnesium fuel wire, so, it must be subtracted from the calculated calorific value.

(ii) Cotton thread correction (C_{CT})

If cotton thread is used for the ignition of fuel, then the heat liberated by cotton (cellulose) must be subtracted from the calculated calorific value of fuel.

(iii) Acid correction (C_A)

If fuel containing sulphur and nitrogen then on

combustion
and
so, the
calculo

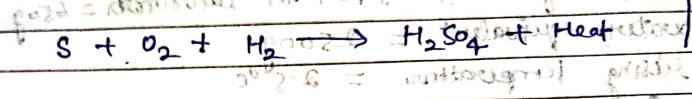
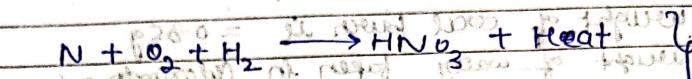
(4) Coal

Due
water
temp
if
of
coal

so

(+) or (-)

In combustion they are converted into sulphuric acid and Nitric acid. Since these reactions are exothermic so, the liberated heat must be subtracted from the calculated heat. (by proportionality calculator derived)



(4) Cooling Correction (C_c)

Due to combustion on fuel the temperature of water rises from room temperature to maximum temperature. But when it cool down to room temp if liberated heat absorbed by the combustion of fuel. So, this heat must be added to the calorific value of fuel. (Therefore = $L + C_c$)

So,

$$L = (W + w)(t_2 - t_1 + C_c) - (C_n + C_F + C_{CT})$$

②

$$100 - 20.828 \times 0.212 = 1.544$$

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(Q) A sample of coke coal containing 89% carbon, 8% hydrogen and 3% ash when they these coal were tested in bomb calorimeter for its calorific value in bomb calorimeter following data was obtained.

Weight of coke broken is = 0.85 g

Weight of water taken in calorimeter = 650 g

Oxygen equivalent = 2500 g

Rising temperature = 2.5 °C

Cooling correction = 0.03 %

Steel correction = 50 calories

Fire wire correction = 10 calories

Assuming latent heat of steam 587 cal/g.

Calculate C.V. and N.C.V. of coal sample

$$\text{Sol: } L = \frac{(W+w)(f_t + f_i + C_c) - (C_A + C_F + C_{ct})}{X}$$

$$L = \frac{(650 + 2500)(2.5 + 0.03) - (50 + 10)}{0.85}$$

$$L = \frac{3150 \times 2.53 + 60}{0.85}$$

$$\therefore L = \frac{7909.5}{0.85} = 9305.29$$

$$N.C.V = 9305.29 - (6 \times 0.09 \times 587)$$

$$= 9305.29 - 422.64$$

$$= 8882.65 \text{ cal/g}$$

Theoretical calculation of calorific value of fuel (Dulong's method)

Theoretically, the calorific value of fuel can be calculated, if the percentage of elements present in the fuel are known then according to Dulong's formula ...

$$G.C.V = \frac{1}{100} [8080 \times C + 34500 \left(\frac{H - O}{8} \right) + 2270 \times S]$$

where C, H and S are % of C, H, S present in fuel.

$$\text{N.C.V} = G.C.V - \text{mass of H} \times g \times \text{latent heat of fusion}$$

B. Calculate Gross and net C.V. of fuel having following composition.

$$C = 82\%, O = 8\%, O = 5\%$$

$$S = 2.5\%, N = 1.4\%, Ash = 2.1\%$$

$$\Rightarrow G.C.V = \frac{1}{100} [8080 \times 82 + 34500 \left(8 - \frac{5}{8} \right) + 2270 \times 2.5]$$

$$\Rightarrow \frac{1}{100} [66256 + \dots]$$

$$\Rightarrow 9225.97 \text{ Kcal / kg.}$$