6.7 Solid Fuels

6.7.1 : Coal

Coal is a highly carbonaceous matter that has been formed as a result of alteration of dead plants and animals under favourable conditions. It is chiefly composed of C, H, N, O, S besides non combustible inorganic matter.

Various types of coal have been recognized on the basis of rank or degree of alteration from the parent material. They are -

$$\text{peat} \longrightarrow \text{lignite} \longrightarrow \text{bituminous coal} \longrightarrow \text{anthracite coal}$$

The transformation into coal has taken millions of years and is accomplished by bacteria, heat and pressure. The transformation of wood to coal is believed to be due to bacterial oxidation under anaerobic conditions resulting into degradation of organic matter.

The transformation results in -

(i) Decrease in moisture content, volatile matter

(ii) Decrease in H, O, N, and S contents with a corresponding rise in carbon content

(iii) Increase in hardness

(iv) Increase in calorific value

6.7.2 : Analysis of Coal

The analysis of coal is necessary to interpret the results from the point of view of classification, price fixation, and industrial utilization of coal. There are two types of analysis : (i) Proximate analysis, and (ii) Ultimate analysis.

6.7.3 : Proximate Analysis

It gives valuable information regarding the practical utility of coal. The grading of coal and industrial uses of coal depends on this analysis.

(a) Determination of Moisture Content

(M.U. May 2018; Nov. 2018)

About 1 gm of air dried coal sample is taken in a crucible and is heated in an electric hot air oven maintained at 105 - 110° C for 1 hour. It is taken out, cooled in a dessicator and weighed. Loss in weight gives the percentage moisture content.

$$\% \text{ Moisture content} = \frac{\text{Loss in weight due to moisture}}{\text{Weight of coal}} \times 100$$

Significance : Moisture in coal evaporates during burning of coal and it takes some of the liberated heat in the form of latent heat of vapourisation. Thus moisture lowers the effective calorific value of coal. Hence lower the moisture content better the quality of coal.

(b) Determination of Volatile Matter Content

(M.U. May 2018)

A known amount of moisture free coal (coal after the determination of moisture content) is taken in a crucible covered with a lid and is heated in a muffle furnace maintained at a temperature 925 ± 20° C. After exactly 7 minutes of heating, the sample is cooled and weighed. Loss in weight gives the percentage of volatile matter content.

$$\% \text{ Volatile matter} = \frac{\text{Loss in weight due to volatile matter}}{\text{Weight of coal}} \times 100$$

Significance : High volatile matter content coal burns with a long smoky flame and gives relatively low calorific value, whereas coal with low volatile matter burns with an intense short flame. Thus larger combustion space is required for coal with high volatile matter content. Hence volatile matter content influences the furnace design.

(c) Determination of Ash Content

The residual coal after the determination of volatile matter is heated without lid in muffle furnace at 700 ± 50° C for half an hour. It is taken out cooled and weighed. The residue is reported as ash.

$$\% \text{ Ash content} = \frac{\text{Weight of the residue}}{\text{Weight of coal}} \times 100$$

Significance : Ash contains silica, alumina, iron oxide and small quantities of lime, magnesia etc. Ash reduces the calorific value. Ash also cause hindrance to the flow of air and heat causing irregular burning of coal and reduce the temperature. It also forms fused ash lumps called clinkers. This can cause obstruction to the free flow of air. Presence of ash increases the transporting, handling and storage costs also. Hence lower the ash content, better the quality of coal.

(d) Determination of Fixed Carbon

$$\% \text{ Fixed carbon} = 100 - \% \text{ (Moisture + Volatile matter + Ash content)}$$

Significance : It is the fixed carbon which burns in the solid state. Higher the fixed carbon greater is its calorific value and better is the quality of coal.

Problem 1

A sample of coal was analyzed for content of moisture, volatile matter and ash. From the following data, calculate the percentage of the above quantities.

(i) Weight of coal taken = 2.5 g

(ii) Weight of coal after heating at 100° C = 2.368 g

(iii) Weight of coal after heating covered crucible at 950 ± 20° C = 1.75 g

(iv) Constant weight obtained at the end of the experiment = 0.95 g

(M.U. Dec. 2009)

Solution :

(i) Weight of coal taken = 2.5 g

$$\text{Mass of moisture in coal sample} = 2.5 - 2.368 = 0.132\ g$$

$$\therefore \text{Percentage of moisture} = \frac{\text{Loss in weight of coal}}{\text{Weight of coal taken}} \times 100 = \frac{0.132 \times 100}{2.5} = 5.28\ \%$$

(ii) $$\text{Mass of volatile matter} = 2.368 - 1.75 = 0.618\ g$$

$$\text{Percentage of volatile matter} = \frac{\text{Loss in weight due to volatile matter}}{\text{Weight of coal}} \times 100 = \frac{0.618 \times 100}{2.5} = 24.72\ \%$$

(iii) $$\text{Mass of ash} = 0.95\ g$$

$$\text{Percentage of ash} = \frac{\text{Weight of ash left}}{\text{Weight of coal taken}} \times 100 = \frac{0.92 \times 100}{2.5} = 38\ \%$$

(iv) $$\%\ \text{of fixed carbon} = 100 - (\%\ \text{moisture} + \text{Volatile matter} + \text{Ash}) = 100 - (5.28 + 24.72 + 38)$$

$$\%\ \text{of fixed carbon} = 100 - 68 = 32\ \%$$

Ans. : % Moisture = 5.28 %

% Volatile Matter = 24.72 %

% Ash = 38 %

% Fixed carbon = 32 %

Problem 2

2.5 g of air dried coal sample was taken in a silica crucible, after heating it in an electric oven at 105-110° C for 1 hour; the residue was weighed 2.410 g. The residue was heated in a silica crucible covered with vented lid at a temperature 950 ± 20° C for exactly 7 minutes. After cooling the weight of residue was found to be 1.78 g. The residue was then ignited at 700-750° C to a constant weight of 0.246 g. Calculate the percentage of fixed carbon in a coal sample. **(M.U. May 2011; Dec. 2013)**

Solution :

(i) Weight of coal taken = 2.5g

Mass of moisture in coal sample = 2.5 − 2.410 = 0.09 g

$$\therefore \text{ Percentage of moisture} = \frac{\text{Loss in weight of coal}}{\text{Weight of coal taken}} \times 100$$

$$\therefore \text{ Percentage of moisture} = \frac{0.09 \times 100}{2.5}$$

$$= 3.6\ \%$$

(ii) Mass of volatile matter = 2.410 − 1.78

$$= 0.63\ g$$

$$\text{Percentage of volatile matter} = \frac{\text{Loss in weight due to volatile matter}}{\text{Weight of coal}} \times 100$$

$$= \frac{0.63 \times 100}{2.5}$$

$$= 25.2\ \%$$

(iii) Mass of residue after ignition at 700-750° C = 0.246 g

$$\therefore \quad \text{Percentage of ash} = \frac{\text{Weight of ash left}}{\text{Weight of coal taken}} \times 100$$

$$= \frac{0.246 \times 100}{2.5}$$

$$= 9.84\ \%$$

(iv) $$\%\text{ of fixed carbon} = 100 - (\%\text{ Moisture} + \text{Volatile matter} + \text{Ash})$$

$$= 100 - (3.6 + 25.2 + 9.84)$$

$$= 100 - 38.64$$

$$= 61.36\ \%$$

Ans. : % of fixed Carbon = 61.36 %

Problem 1

1.5 g of coal sample was taken for C and H estimation by combustion method. The increase on weight of tube containing anhydrous $CaCl_2$ and bulb containing KOH was found to be 1.25 g and 4.88 g respectively. Calculate the percentage of C and H

(M.U. Dec. 2008, 2011)

Solution :

(i) Increase in weight of KOH tube = 4.88 g

$$\% \text{ of C} = \frac{\text{Increase in weight of KOH tube} \times 12 \times 100}{\text{Weight of coal taken} \times 44}$$

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

$$= \frac{5856}{66}$$

$$= 88.72\ \%$$

(ii) Increase in weight of $CaCl_2$ tube = 1.25 g

$$\% \text{ of H} = \frac{\text{Increase in weight of } CaCl_2 \text{ tube} \times 2 \times 100}{\text{Weight of coal sample} \times 18}$$

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

$$= 9.26\ \%$$

Ans. : % of carbon = 88.72 %

% of hydrogen = 9.26 %

Problem 2

1.95 g 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 weighing 1.5 g in Bomb calorimeter experiment produced 0.35 g of $BaSO_4$. Calculate percentage of N and S. **(M.U. Dec. 2008 ; May 2011, 2018)**

Solution :

(i) Volume of acid used = 9.5 ml of 0.4 N H_2SO_4

Weight of coal sample = 1.95 g

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

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

$$= 2.73 \%$$

(ii) Weight of coal sample = 1.5 g

Weight of $BaSO_4$ ppt. = 0.35 g

$$\% \text{ of sulphur} = \frac{\text{Weight of } BaSO_4 \text{ ppt.} \times 32 \times 100}{\text{Weight of coal} \times 233}$$

$$= \frac{0.35 \times 32 \times 100}{1.5 \times 233}$$

$$= \frac{1120}{349.5}$$

$$= 3.205 \%$$

Ans. : % of nitrogen = 2.7 %

% of sulphur = 3.205 %