ANALYSIS OF COAL

Coal is a fossil fuel which occurs in layers in the earths crust. It is formed by the partial decay of plant materials accumulated millions of years of ago and further altered by action of heat and pressure. The process of conversion of wood into coal can be represented as

Wood $\longrightarrow$ Peat $\longrightarrow$ Lignite $\longrightarrow$ Bituminous $\longrightarrow$ Anthracite

1) Peat: Peat is brown-fibrous jelly like mass.

2) Lignite: these are soft, brown colored, lowest rank coals

3) Bituminous coals: These are pitch black to dark grey coal

4) Anthracite: It is a class of highest rank coal

Fuel	Percentage of carbon	Calorific value (k.cal/kg)	Applications
Wood	50	4000-5000	Domestic fuel
Peat	50-60	4125-5400	Used if deficiency of high rank coal
Lignite	60-70	6500-7100	For steam generation in thermal power plants
Bituminous	80-90		In making coal gas and Metallurgical coke
Anthracite	90-98	8650-8700	In households and for steam raising

Analysis of Coal

The analysis of coal is helpful in its ranking.

The assessment of the quality of coal is carried out by these two types of analyses.

A) Proximate analysis B) Ultimate analysis

Proximate analysis: In this analysis, the percentage of carbon is indirectly determined. It is a quantitative analysis of the following parameters.

1. Moisture content 2. Volatile matter 3. Ash 4. Fixed carbon

Moisture Content: About 1 gram of finely powdered air-dried coal sample is weighed in a crucible. The crucible is placed inside an electric hot air-oven, maintained at 105 to 110 ^{0}C for one hour. The crucible is allowed to remain in oven for 1 hour and then taken out, cooled in desiccators and weighed. The process of heating, cooling and weighing of crucible is repeated until we get a constant weight. Loss in weight is reported as moisture.

$$\boldsymbol{Percentage\ of\ Moisture = \frac{Loss\ in\ weight\ of\ coal}{Weight\ of\ coal\ taken} \times 100}$$

Volatile Matter: The volatile matter present in the coal may be combustible gases (CH_4, CO, H_2 etc.) or non-combustible gases (CO_2, N_2).

The dried sample (moisture free coal) taken in a crucible in and then covered with a lid and placed in an electric furnace or muffle furnace, maintained at 925 ± 20 ^{o}C. The crucible is taken out of the oven after 7 minutes of heating. The crucible is cooled first in air, then inside desiccators and weighed again. The process of heating, cooling and weighing of crucible is repeated until we get a constant weight. Loss in weight is reported as volatile matter on percentage-basis.

$$\boldsymbol{Percentage\ of\ Volatile\ Matter = \frac{Loss\ in\ weight\ of\ coal}{Weight\ of\ coal\ taken} \times 100}$$

Ash: Ash is the non combustible, useless matter which is left behind after the combustion of coal. Ash content reduces the calorific value of coal.

The weighed amount of coal sample is taken in a crucible and then heated without lid in a muffle furnace at 700 ± 50 ^{o}C for ½ hour. The crucible is then taken out, cooled first in air, then in desiccators and weighed. Hearing, cooling and weighing are repeated, till a constant weight is obtained. The residue is reported as ash on percentage-basis.

$$\boldsymbol{Percentage\ of\ Ash = \frac{Weight\ of\ ash\ formed}{Weight\ of\ coal\ taken} \times 100}$$

Fixed carbon:

Percentage of fixed carbon = 100 - % of (Moisture + Volatile matter + Ash)

Significance of proximate analysis: Proximate analysis provides following valuable information's in assessing the quality of coal.

Moisture: Moisture is coal evaporates during the burning of coal and it takes some of the liberated heat in the form of latent heat of evaporation. Therefore, moisture lowers the effective calorific value of coal. Moreover over, it quenches the fire in the furnace, hence, lesser, the moisture content, better the quality of coal as a fuel. However, presence of moisture, up to 10%, produces a more uniform fuel-bed and less of "fly-ash".

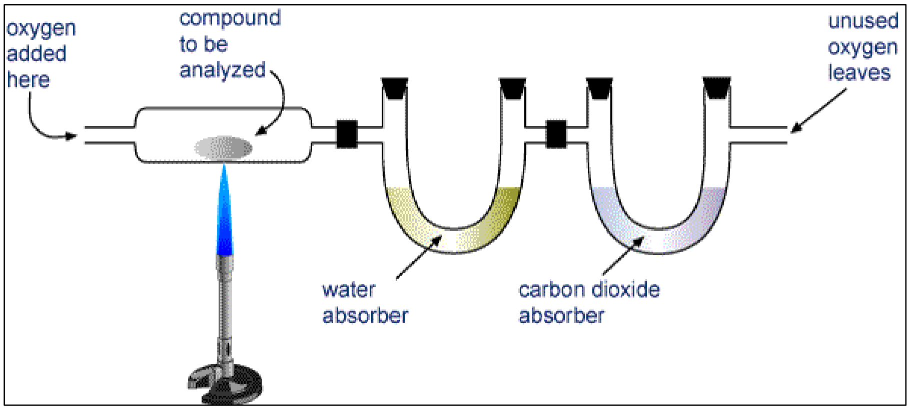
Volatile matter: A high volatile matter content means that a high proportion of fuel will distil over as gas or vapour, a large proportion of which escapes un-burnt, So, higher volatile content in coal s undesirable. A high volatile matter containing coal burns with a long flame, high smoke and has low calorific value. Hence, lesser the volatile matter, better the rank of the coal.

Ash: Ash is a useless, non-combustible matter, which reduces the calorific value of coal. Moreover, ash causes the hindrance to the flow of air and heat, thereby lowering the temperature. Also, it often causes trouble during firing by forming clinkers, which block the interspaces of the grate, on which coal is being burnt. This in-turn causes obstruction to air supply; thereby the burning of coal becomes irregular. Hence, lower the ash content, better the quality of coal. The presence of ash also increases transporting, handling and storage costs. It also involves additional cost in ash disposal. The presence of ash also causes early wear of furnace walls, burning of apparatus and feeding mechanism.

Fixed carbon: Higher the percentage of fixed carbon, greater is it's calorific and betters the quality coal. Greater the percentage of fixed carbon, smaller is the percentage of volatile matter. This also represents the quantity of carbon that can be burnt by a primary current of air drawn through the hot bed of a fuel. Hence, high percentage of fixed carbon is desirable. The percentage of fixed carbon helps in designing the furnace and the shape of the fire-box, because it is the fixed carbon that burns in the solid state.

Ultimate analysis: This is the elemental analysis and often called as qualitative analysis of coal. This analysis involves the determination of carbon and hydrogen, nitrogen, sulphur and oxygen.

Determination of Carbon and Hydrogen: About 1 to 2 gram of accurately weighed coal sample is burnt in a current of oxygen in a combustion apparatus. C and H of the coal are converted into CO_2 and H_2O respectively. The gaseous products of combustion are absorbed respectively in KOH and $CaCl_2$ tubes of known weights.



$CaCl_2$ tube absorbs moisture:

$$CaCl_2 + 7\,H_2O \longrightarrow CaCl_2.7H_2O$$

While KOH bulb absorbs CO2:

$$2KOH + CO_2 \longrightarrow K_2CO_3 + H_2O$$

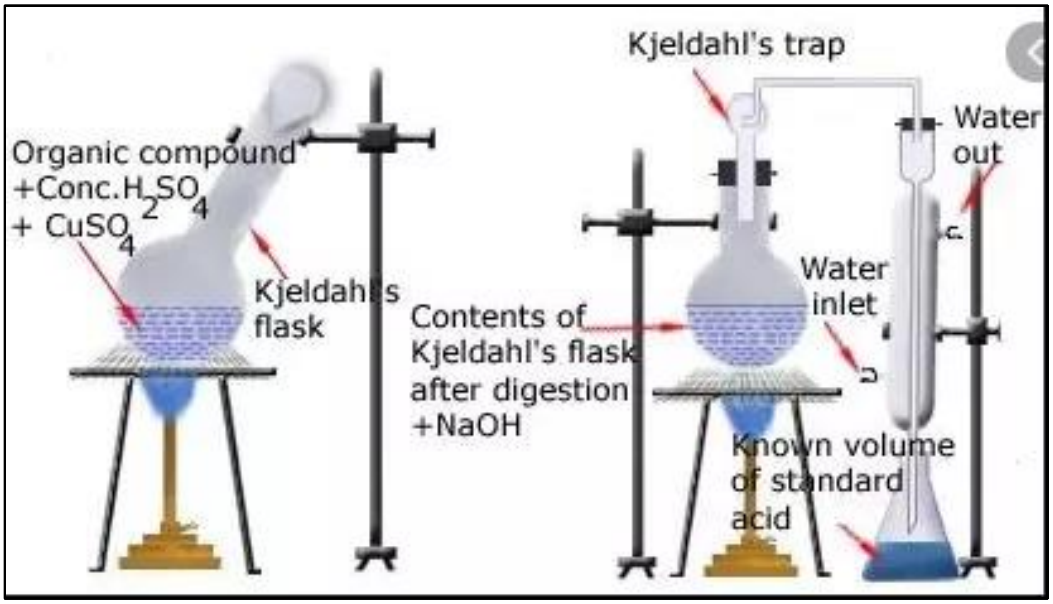
The increase in weight of $CaCl_2$ tube represents the weight of water formed while the increase in weight of KOH bulb represents the weight of CO_2 formed.

$$\textit{Percentage of Carbon} = \frac{\textit{Increase in weight of KOH tube} \times 12}{\textit{Weight of coal sample taken} \times 44} \times 100$$

$$\textit{Percentage of Hydrogen} = \frac{\textit{Increase in weight of } CaCl_2 \textit{ tube} \times 2}{\textit{Weight of coal sample taken} \times 18} \times 100$$

Determination of Nitrogen: A good coal should have very little nitrogen content.

Kjeldahal's Method: About 1 gram of accurately weighed powdered coal is heated with concentrated H_2SO_4 along with K_2SO_4 and $CuSO_4$ (catalyst) in a long-necked Kjeldahl's flask. After the solution becomes clear (when whole nitrogen is converted into ammonium sulphate) , it is treated with excess of KOH and the liberated ammonia is distilled over and absorbed in a known volume (V_1) of standard H_2SO_4 solution (0.1 N). The unused acid is then determined by back titration with standard NaOH solution (0.1 N).



$$\mathbf{N_2 + H_2SO_4 \longrightarrow (NH_4)_2SO_4}$$

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

$$\mathbf{2NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4}$$

Let V_2 ml of 0.1 N NaOH was required to neutralize excess acid, the percentage of N in coal is calculated as follows:

$$\boldsymbol{Percentage\ of\ Nitrogen} = \frac{\mathbf{0.1\ (}\boldsymbol{V_1 - V_2}\mathbf{)}}{\boldsymbol{Weight\ of\ coal\ taken}} \times \mathbf{1.4}$$

Determination of Sulfur: Although sulfur increases the calorific value of, on oxidation it produces harmful and corrosion causing SO_2 and SO_3 gases.

A known amount of coal is burnt in bomb calorimeter in presence of oxygen, by which Sulphur present in coal is converted into sulphates. The ash obtained in bomb calorimeter is treated with dil HCl. It is then treated with Barium chloride solution, when barium sulphate is precipitated. This precipitate is filtered, washed and heated to constant weight.

$$\boldsymbol{Percentage\ of\ Sulfur\ in\ coal = \frac{Weight\ of\ BaSO_4\ ppt\ \times 32}{Weight\ of\ coal\ taken\ \times 233} \times 100}$$

Determination of Ash: Same as proximate analysis.

Determination of Oxygen:

It is determined indirectly by deducting the combined percentage of carbon, hydrogen, nitrogen, sulphur and ash from 100.

Percentage of Oxygen = 100 – percentage of (C + H + S + N + Ash)

Significance of ultimate analysis:

Carbon and Hydrogen: Greater the percentage of carbon and hydrogen better is the coal in quality and calorific value. However, hydrogen is mostly associated with the volatile mater and hence, it affects the use to which the coal is put.

Nitrogen: Nitrogen has no calorific value and hence, its presence in coal is undesirable. Thus, a good quality coal should have very little nitrogen content.

Sulphur: Sulphur, although contributes to the heating value of coal, yet on combustion produces acids like SO_2, SO_3, which have harmful effects of corroding the equipment's and also cause atmospheric pollution. Sulphur is, usually, present to the extent of 0.5 to 0.3% and derived from ores like iron, pyrites, gypsum, etc., mines along with the coal. Presence of sulphur is highly undesirable in coal to be used for making coke for iron industry. Since it is transferred to the iron metal and badly affects the quality and properties of steel. Moreover, oxides of sulphur pollute the atmosphere and leads to corrosion.

Ash: Ash is a useless, non-combustible matter, which reduces the calorific value of coal. Moreover, ash causes the hindrance to the flow of air and heat, thereby lowering the temperature. Hence, lower the ash content, better the quality of coal. The presence of ash also increases transporting, handling and storage costs. It also involves additional cost in ash disposal. The presence of ash also causes early wear of furnace walls, burning of apparatus and feeding mechanism.

Oxygen: Oxygen content decreases the calorific value of coal. High oxygen-content coals are characterized by high inherent moisture, low calorific value, and low coking power. Moreover, oxygen is a combined form with hydrogen in coal and thus, hydrogen available for combustion is lesser than actual one. An increase in 1% oxygen content decreases the calorific value by about 1.7% and hence, oxygen is undesirable. Thus, a good quality coal should have low percentage of oxygen.