FUELS

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Syllabus

- Introduction
- classification of fuels
- characteristics of a good fuel
- calorific value; HCV and LCV, Dulong's formula
- Determination of calorific value by Bomb Colorimeter
- Numerical problems
- Coal: analysis of coal - proximate and ultimate analysis significance of the analysis.

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Introduction

- Fuel is a combustible substance containing carbon as the main constituent which on proper burning gives a large amount of heat that can be used economically for domestic and industrial purpose.

- The various fuels used economically are wood, coal, kerosene, petrol, diesel, gasoline, coal gas, producer gas, water gas, natural gas etc.

Classification of fuels

- Classification of Fuels
  - Primary or Natural
    - Solid: Wood, coal
    - Liquid: Crude oil
    - Gaseous: Natural gas
  - Secondary/Derived
    - Solid: Charcoal
    - Liquid: Kerosene, petrol
    - Gaseous: Biogas, CNG

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FUELS

Wood

Crude oil

Natural Gas

Charcoal

Kerosene

CNG

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CHARACTERISTICS OF GOOD FUELS:

- High Calorific Values
- Moderate Ignition Temperature
- Low Moisture Content
- Low Ash Content
- Should not produce harmful products such as CO_2 ,SO_2, H_2S which are toxic and cause pollution
- Low Cost
- Easy Storage
- Easy Transportation

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Calorific Value

- Calorific Value: Calorific Value of a fuel is the total quantity of heat liberated by complete combustion of a unit mass (or volume) of the fuel.

It can be expressed as:

Calorie → Kilocalorie → British Thermal Unit → Centigrade Heat Unit

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H.C.V and L.C.V

- **High or Gross Calorific Value (H.C.V. or G.C.V.) :** It is the total amount of heat liberated, when a unit mass/volume of the fuel has been burnt completely and the products of combustion have been cooled to room temperature
- **Low or Net Calorific Value (L.C.V. Or N.C.V):** It is the net amount of heat liberated, when a unit mass/volume of the fuel is burnt completely and the products of combustion are allowed to escape.

Relation between HCV & LCV:

- These can be related as:

LCV = HCV – Latent heat of water vapor formed

= HCV – (Mass of Hydrogen × 9 × Latent heat of steam)

Dulong's formula

Dulong's formula for calculating the calorific value is given as:

Gross calorific Value (HCV)

$$= \frac{1}{100}[8080C + 34{,}500(H - \frac{O}{8}) + 2{,}240S]kcal/kg$$

Net Calorific value (LCV)

$$= [HCV - \frac{9H}{100} \times 587]kcal/kg$$

$$= [HCV - 0.09H \times 587]kcal/kg$$

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Contd.

- Where C= % Carbon, H= % Hydrogen, O = % Oxygen and S = % Sulphur respectively.

BOMB CALORIMETER

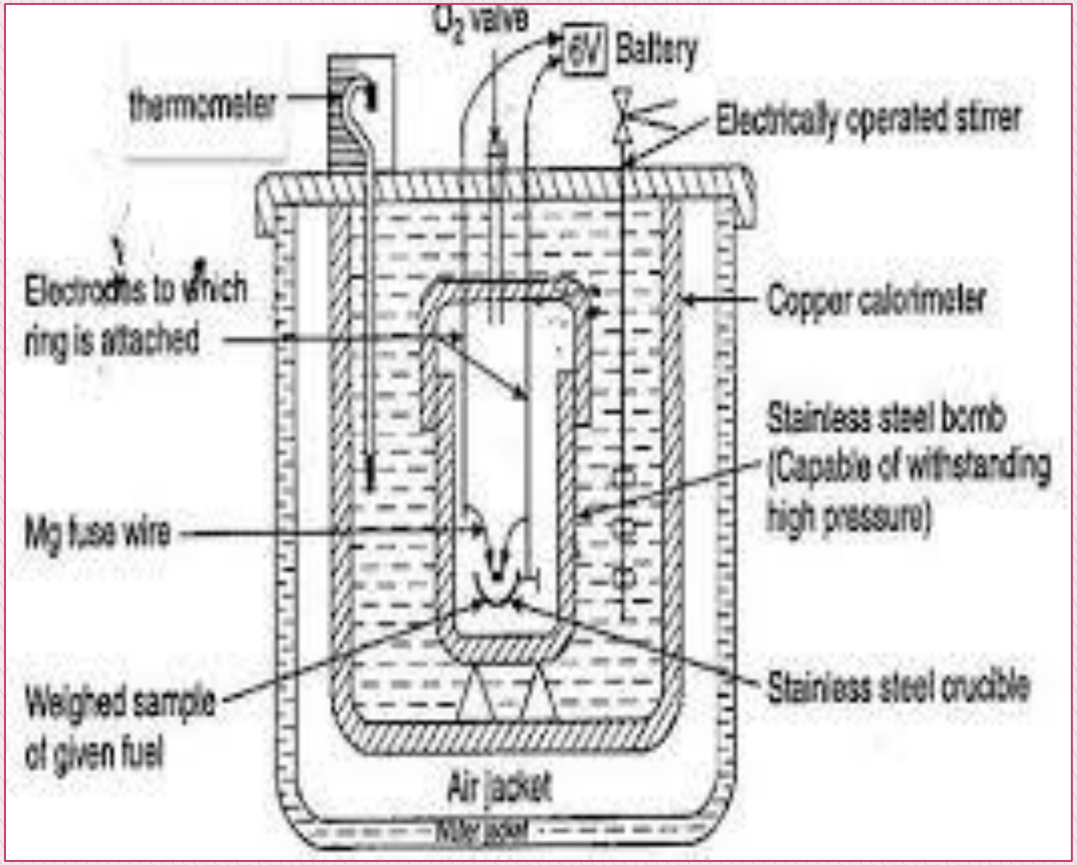
This apparatus is used to find the calorific value of solid and liquid fuels.

- Construction of Bomb calorimeter: a bomb calorimeter consists of the following:
- ✓ A stainless steel bomb in which a combustion of fuel is made to take place
- ✓ Two Electrodes and an oxygen inlet valve
- ✓ Nickel or stainless steel crucible
- ✓ The bomb is placed in copper calorimeter, which is surrounded by air and water jacket to prevent heat losses due to radiation
- ✓ The calorimeter is provided with electrically operated stirrer and Beckmann's thermometer which can accurately read temperature difference upto $1/100^{th}$ of a degree

BOMB CALORIMETER

Working of Bomb calorimeter: A known mass of the given fuel is taken in nickel crucible supported over a ring inside the steel bomb which is connected with two electrodes. The bomb lid is tightly screwed and filled with O_2 upto 25 atm. Pressure. The bomb is then lowered into the copper calorimeter containing known mass of water. The water is stirred with the help of mechanical stirrer and the initial temp is recorded. The electrodes are then connected to 6 volt battery and the circuit is completed. The sample burns and the heat is liberated. Uniform stirring of water is continued and the maximum temp. attained is recorded.

BOMB CALORIMETER SETUP



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CALCULATION OF BOMB CALORIMETER

weight of the fuel sample taken = x g

Weight of water in the calorimeter = W g

Water equivalent of the Calorimeter, stirrer, bomb, thermometer = w g

Initial temperature of water = $t_1{}^0C$

Final temperature of water = $t_2{}^0C$

Higher or gross calorific value = L cal/g

Heat gained by Calorimeter = $(W+w)\ (t_2 - t_1)$ cal

Heat liberated by the fuel = x L cal

Heat liberated by the fuel = Heat gained by water and calorimeter

$$x\,L = (W+w)\ (t_2 - t_1)$$

$$L = \frac{(W+w)\ (t_2 - t_1)}{x} \text{ cal/g or Kcal/kg}$$

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Corrections

To get more accurate results, the following corrections are applied:

- Fuse wire correction
- Acid correction
- Cooling correction

$$L = \frac{(W+w)(t_2 - t_1 + \text{cooling correction}) - (\text{acid} + \text{fuse corrections})}{x} \text{ cal/g or Kcal/kg}$$

Analysis of Coal

- Coal Analysis techniques are specific analytical methods designed to measure the particular physical and chemical properties of coal. There are two methods to analyze coal i.e, the proximate analysis and the ultimate analysis.
- **The proximate analysis** determines only the fixed carbon, volatile matter, moisture and ash percentages.
- Useful to find out HCV
- Needs simple analysis Equipment

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Proximate Analysis

Proximate analysis involves the following determinations in terms of percentage by weight:

Moisture means the water expelled from the fuel by specified methods without causing any chemical change to the fuel. Hence, lesser the moisture content better is the quality of fuel.

Volatile matter is the loss in weight minus the moisture when the fuel is heated to a sufficiently high temperature under specified conditions. A high volatile matter containing coal burns with a long flame, high smoke and has low calorific value.

Ash is the inorganic residue left when the fuel is completely burnt in air under specified conditions.

Fixed carbon is the residue obtained by subtracting the sum of the percentages by weight of moisture, volatile matter and ash from 100. It is essentially carbon containing minor amounts of nitrogen, sulphur, oxygen and hydrogen.

Proximate Analysis

- Moisture content: 1 g of finely powdered coal, taken in a crucible, is heated in an electric oven at 105-110 ^{0}C for 1 hour, cooled in a dessicator and weighed. Percentage moisture content can be calculated from the loss of weight.

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

- Volatile matter: For determining volatile matter content, the dried sample of coal left in the crucible is then covered with a lid and is placed in a muffle furnace at 925°C ± 20°C for exactly seven minutes. The crucible is cooled first in air, then in the dessicator and weighed. The loss in weight is due to volatile matter which is calculated as:

$$\% \text{ Volatile matter} = \frac{\text{loss in wt}}{\text{wt of coal sample}} \times 100$$

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Proximate Analysis

- **Ash content:** It is the residue obtained after burning of the coal in a muffle furnace at 700-750 ^{0}C for half an hour till a constant weight is obtained.

$$\% \text{ of Ash} = \frac{\text{wt of residue left}}{\text{wt of coal taken}} \times 100$$

- **Fixed carbon content:** It is determined indirectly by deducting the sum of total moisture, volatile matter and ash content from 100.

% of Fixed carbon = 100 – (% of moisture + % of volatile matter +% of ash)

Ultimate Analysis

- Ultimate analysis is also known as elemental analysis, it is the method to determine the Carbon, Hydrogen, Nitrogen, Sulphur and Oxygen content present in the solid fuel.
- Determination of % of C & H: Accurately weighed coal sample is burnt in a combustion apparatus. Carbon and hydrogen of coal are converted into carbon-dioxide and water vapour respectively. The products of combustion are absorbed respectively in KOH and $CaCl_2$ tubes respectively of known weights. After complete absorption of CO_2 and H_2O , the tubes are again weighed.

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

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

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Ultimate Analysis

- Determination of Nitrogen: Nitrogen is calculated by Kjeldahl's Method. The nitrogen is converted to NH_3 and passed through a known volume of standard acid. On neutralization, the excess acid is back titrated with a base.

$$\% N = \frac{\text{volume of acid used} \times \text{Normality} \times 1.4}{\text{wt of coal taken}}$$

- Determination of Sulphur: during this determination S is converted into sulphate. The washings are treated with barium chloride solution and gets converted to barium sulphate precipitate. The precipitate is filtered, washed and heated to constant weight.

Ultimate Analysis

$$\% \text{ Sulphur} = \frac{\text{wt of } BaSO_4 \text{ obtained} \times 32 \times 100}{\text{wt of coal taken} \times 233}$$

- **Determination of Ash:** ash determination is carried out as in proximate analysis
- **Determination of Oxygen:** The oxygen is determined indirectly by calculation as:

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

Significance of the analysis:

- The proximate analysis involves the determination of moisture, volatile matter, ash, and fixed carbon. This gives quick and valuable information regarding commercial classification and determination of suitability for a particular industrial use.
- The ultimate analysis involves the determination of carbon, hydrogen, sulphur, nitrogen, oxygen and ash. The ultimate analysis is essential for calculating heat balances in any process for which coal is employed as a fuel.

Reference Books

- Engineering Chemistry by Jain & Jain
- A text book of Engineering Chemistry by S. S.Dara