FUELS

Introduction: A fuel is a substance that contains carbon and hydrogen undergoes combustion in presence of oxygen to gives large amount of energy.

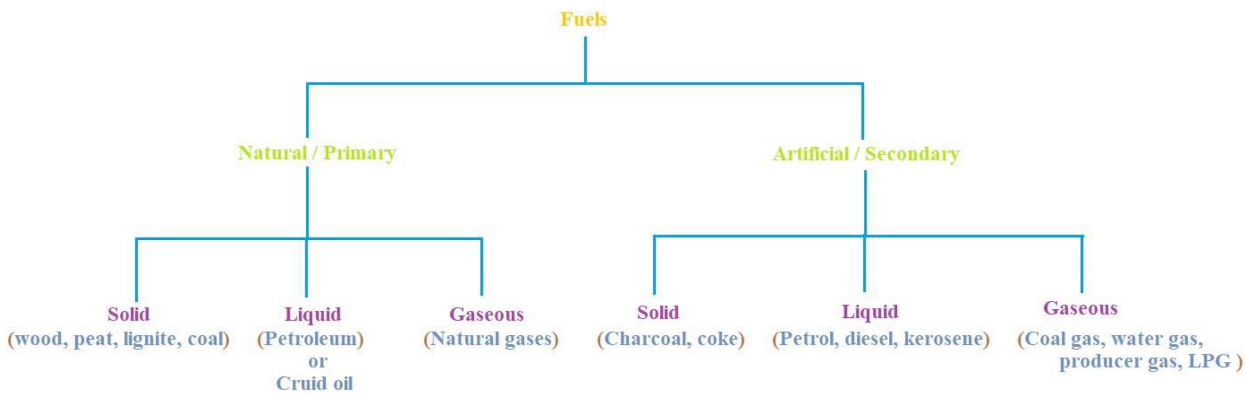
$$Fuel + O_2 \longrightarrow CO_2 + H_2O + Energy$$

Classification of Fuel

On the basis of occurrence fuel is classified into two categories; natural or primary fuels and artificial or secondary fuels.

Natural/primary fuels: These fuels are naturally present.

Artificial/ secondary fuels: They are synthesized by primary fuels.



Characteristics of Good Fuel

- Fuel should have high calorific value.
- Must have moderate ignition temperature.
- Fuel should have low moisture content.
- Available in bulk at low cost.
- Should not burn spontaneously.
- Fuel should burn efficiently, without releasing hazardous pollutants.
- Handling, storage and transportation should be easy.

Unit of heat

i) **Calorie**: it is the amount of heat required to raise the temperature of 1 gram of water through one degree centigrade.

ii) **British Thermal Unit (BTU):** it is the amount of heat required to raise the temperature of 1 pond of water to one degree Fahrenheit.

$$1 \text{ B.T.U.} = 252 \text{ cal} = 0.252 \text{ kcal}$$

1 kcal = 3.968 B.T.U.

Centigrade Heat Unit (CHU): it is define as the amount of heat required to raise the temperature of 1 pond of water to one degree centigrade.

1 kcal = 3.968 B.T.U. = 2.2 C.H.U.

Calorific value: Calorific value of fuel can be define as the amount of heat evolved when one unit mass or volume of the fuel undergoes completely combustion in presence of oxygen.

High or gross calorific value (HCV or GCV): It is defined as amount of heat evolve when one unit mass or volume of the fuel is completely burnt and combustible products are cooled to room temperature (25^{o}C or 77^{o}F).

Low or net calorific value (LCV or NCV): it is defined as amount of heat evolve when one unit mass or volume of the fuel is completely burnt and combustible products are permitted to escape. Therefore net calorific value is lower than gross calorific value.

LCV = HCV – latent heat of water vapour

LCV = HCV – mass of hydrogen × 9 × latent heat of steam (587 kcal/kg)

One part by mass of hydrogen produced nine parts by mass of water molecule. Therefore, LCV = HCV – H/100 × **9** × 587 kcal/kg

Where, H = percentage of hydrogen in fuel

Dulong Formula: In this formula the higher calorific value (HCV) of a fuel is the total of the calorific value of each of the components.

H.C.V. = 1/100 [8080 x %C + 34500 (%H - % O/8) + 2240 x %S]

Problem:

Calculate the gross and net calorific value of a coal sample having the following composition C = 80%, H = 7%, O = 3%, S = 3.5%, N = 2% and ash = 5%.

Solution:

H.C.V. = 1/100 [8080 x %C + 34500 (%H - % O/8) + 2240 x %S]
= 1/100 [8080 x 80 + 34500 x (7 – 3/8) + 2240 x 3.5]
= 8828 cal/gm.

L.C.V. = H.C.V – 0.09 x %H x 587
= 8828 – 0.09 x 7 x 587
= 8458 cal/gm.

ANALYSIS OF COAL

The quality of coal can be measured by the following two type of analysis:

PROXIMATE ANALYSIS: The following parameters will be determined in this analysis.

Moisture: About 1 g of finely powdered air dried coal sample is weighed in a crucible. The crucible is placed inside an electric hot air oven, maintained at $105^0 - 110^0C$. The crucible is allowed to remain in oven for 1hr and then take out, cooled in desiccators and weighed. Loss in weight is reported as moisture content on percentage basis.

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

Importance/significance: Less the moisture content, better the quality of coal. But, 10% moisture can be present to produce a more uniform fuel-bed and less of fly ash.

Volatile matter: The dried sample of coal left in the crucible in (1) is then covered with a lid and heated in an electric furnace (muffle furnace) at 950^0C for 7 minutes. The loss in weight reported as volatile matter on percentage basis.

$$= \frac{\text{Loss in weight due to removed of volatile matter}}{\text{Wt. of coal sample taken}} \times 100$$

Importance/significance: High volatile matter content is undesirable because, high volatile matter containing coal burns with long flame, high smoke and has low calorific value, so better quality of coal should have less volatile matter.

Ash: The residual coal in the crucible is then healed without lid in a muffle furnace at 700^0C for half an hour. Then the crucible is cooled in air then desicator. Weight of the coal is noted again it is heated, then cooled and weighed.

$$\text{Percentage of ash} = \frac{\text{Wt. of ash left}}{\text{Wt. of coal taken}} \times 100$$

Importance significance: As is useless non combustible matter which reduces the calorific value of the coal. It can cause hindrance for the flow of heat and air. And also it can block the passage of coal.

Fixed Carbon: % of fixed carbon = 100 – [% of moisture + % of Volatile matter + % of ash]

Importance/ significance: grater the percentage of fixed carbon, higher the calorific value of coal.

ULTIMATE ANALYSIS: Involves in the determination elemental composition.

Carbon and Hydrogen: Known weight of coal sample is burnt in a current of oxygen in combustion apparatus. Then the carbon and hydrogen are converted into CO_2 and H_2O respectively. These are absorbed by KOH and $CaCl_2$ of known weight of these compounds is due to the weights contributed by CO_2 and H_2O.

$$\underset{(12)}{C} + O_2 \longrightarrow \underset{(44)}{CO_2} \quad ; \quad \underset{(2)}{H_2} + \underset{(16)}{\tfrac{1}{2}O_2} \longrightarrow \underset{(18)}{H_2O}$$

$$2KOH + CO_2 \longrightarrow K_2CO_3 + H2O$$

$$CaCl_2 + 2H_2O \longrightarrow CaCl_2.7H_2O$$

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

$$\text{and percentage of H} = \frac{\text{increase in weight of CaCl}_2\text{ tube} \times 2 \times 100}{\text{Weight of coal sample taken} \times 18}$$

Importance significance: Higher the percentage of carbon and hydrogen in the coal sample better is the quality of coal. But, presence of excess of hydrogen indicates presence of high volatile matter.

Nitrogen: Known weight of powdered coal is heated with mixture of H_2SO_4 and K_2SO_4(catalyst) in a long necked flask (Kjeldhal flask), After the solution becomes clear, it is treated with excess of NaOH and liberated ammonia is distilled over the absorbed in known volume of std. acid solution. The unused acid is then determined by standard alkali (back titration). Then we can find out the volume of the acid reacted with ammonia.

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

Importance significance: nitrogen does not contribute to calorific value, its presence is undesirable. A good quality of coal should have very low percentage of nitrogen.

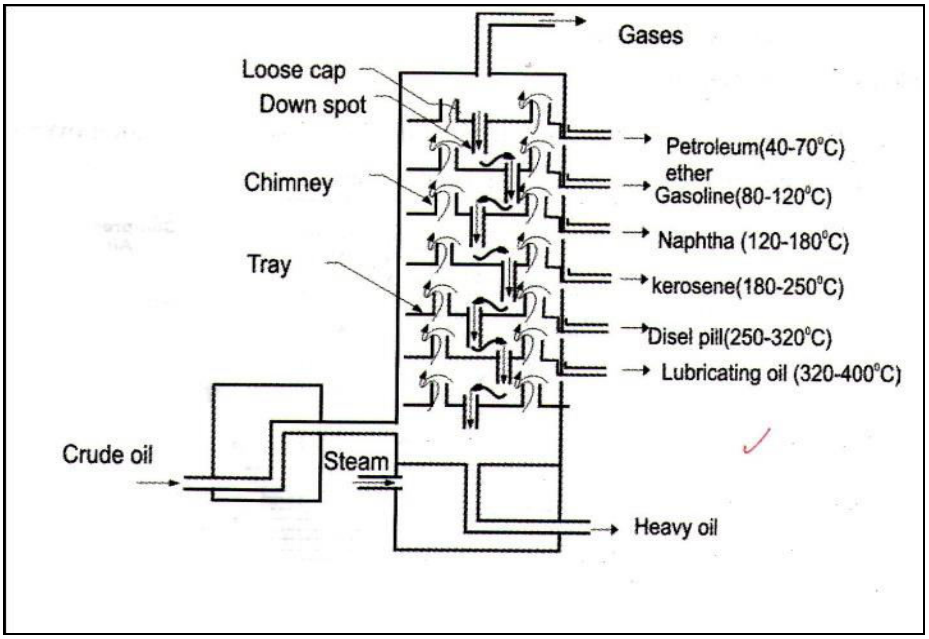
Sulfur: Percentage of Sulfur in the coal can be determined from washings of bomb calorimeter. In this process, 'S' is converted into sulfates, upon treatment with barium chloride. A precipitate of barium sulfate is formed, and then the precipitate is filtered washed and heated and weighed.

$$\text{Percentage of S} = \frac{\text{Weight of Ba}SO_4\text{ obtained} \times 32 \times 100}{\text{Weight of coal sample taken in bomb} \times 233}$$

Importance significance: Sulfur has some calorific value but the product of combustion i.e. oxides of Sulfur are harmful to the equipment and environment.

Oxygen: Percentage of oxygen = 100 – [%C + % H + % N + % S + %Ash]

FRACTIONAL DISTILLATION OF PETROLEUM

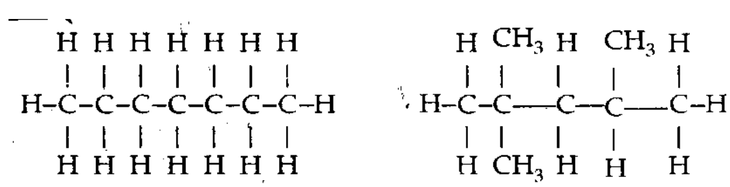


The crude oil is then heated to about 400°C in an iron retort, whereby all volatile constituents, except the residue (asphalt and coke) are evaporated. The vapors are then passed up a "fractionating column", which a Tall cylindrical tower is containing a number of horizontal stainless steel trays at short distances. Each tray is provided with small chimney, covered with a loose cap. As the vapors go up, they become gradually cooler and fractional condensation takes place at different heights of column. Higher boiling point fractions condense first; while the lower boiling fractions turn by turn. Various principal fractions product thus obtained are given in the table.

Fraction	Boiling Point Range(^{0}c)	Composition	Uses
Uncondensed gases	≤ 30	C_1 - C_4	Domestic fuel (L.P.G).
Petroleum ether	30 - 70	C_5 - C_7	As a solvent.

Gasoline (or) petrol	40 - 120	C_5 - C_9	As a fuel, solvent and dry cleaning.
Naphtha	120 - 180	C_9 - C_{10}	As a solvent and dry cleaning.
Kerosene	180 - 250	C_{10} - C_{16}	Jet engine fuel.
Diesel	250 - 320	C_{10} - C_{19}	As a diesel engine fuel.
Heavy oil	320 - 400	C_{17} - C_{30}	Used for getting petrol by cracking.
Refraction of heavy oil gives 1. Lubricant oil 2. Petroleum jelly 3. Grease 4. Paraffin wax 5. Tar	≥400	C_{17} - C_{20}	As lubricant In cosmetics & medicines Used for making candles Boot polish, wax paper

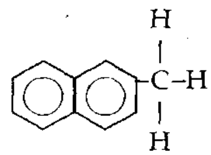
Octane Number: It has been found that n- heptane knocks very badly and hence its anti-knock value has arbitrarily been given zero. On the other hand isooctane (2, 2, 4-trirnethyl pentane) gives very little knocking, so its anti-knock value has been given as '100. Thus, octane number (or rating) of a gasoline is the percentage of iso octane in a mixture of isooctane and n-heptane, which matches the fuel under test in knocking characteristics. In this way, an "80-octane" fuel is one which has the same combustion characteristics as an 80:20 mixture of isooctane and n-heptane.



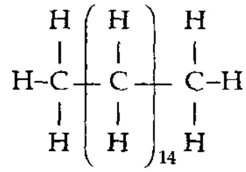
(Octane No. = 0) (Octane No. = 100)

Cetane Number: The suitability of a diesel fuel is determined by its cetane value, which is the percentage of hexadecane in a mixture of hexadecane and 2- methyl naphthalene, which has the same ignition characteristics as the diesel fuel in question. The cetane number of a diesel fuel be raised by the addition of small quantity of certain "pre- ignition dopes" like ethyl nitrite, isoamyl nitrite and acetone peroxide etc. Ignition quality order among hydrocarbon constituents of a diesel fuel is as follows:

n-alkanes> alkenes > branched alkanes >naphthalenes>aromatics.



- · Methyl naphthalene
(*Cetane No. = 0*)



n - Hexadecane
(*Cetane No. = 100*)

ALTERNATIVE FUELS

Alternative fuels, known as non-conventional and advanced fuels, are any materials or substances that can be used as fuels, other than conventional fuels like; fossil fuels, as well as nuclear materials such as uranium and thorium, as well as artificial radioisotope fuels that are made in nuclear reactors.

Methanol: Methanol is an alternative bio fuel. It can be used directly in motor engines or blended with petrol.

Preparation: methanol can be prepared from CO_2 and H_2. Presently it is producing from methane as a raw material.

Advantages: With the advent of flexi-fuel vehicles (FFV) in the 1990s, the methanol became a prime candidate for use in vehicles because of its lower emission characteristics and high-octane rating. To solve the cold-start problems in methanol, a percentage of gasoline is added. Blends of 15% gasoline and 85% of methanol are called M85. Currently, methanol is again considered for fuel cell vehicles; that is, methanol is used as fuel to derive the hydrogen for the operation of fuel cells

Ethanol: Ethyl alcohol, commercially known as ethanol, possesses a number of characteristics favoring its use as an automobile fuel. Ethanol is a by-product in the production of sugar. Ethanol is a renewable fuel made from corn and other plant materials. At present, ethanol is blended with gasoline for improving the octane number of gasoline. Ethanol molecules contain oxygen and therefore, it allows the engine to completely combust the fuel, resulting in less emission of carcinogenic gases like carbon monoxide, NOx, and so on. The most common blend of ethanol is E10 (10% ethanol, 90% gasoline). The auto ignition temperature of ethanol is significantly higher than gasoline and this makes ethanol less susceptible to ignition.

$$C_6H_{12}0_6 \longrightarrow 2C_2H_5OH + 2CO_2 + \text{Heat}$$

Propane: Liquefied petroleum gas or liquid petroleum gas (LPG or LP gas), also referred to as simply propane or butane, are flammable mixtures of hydrocarbon gases used as fuel in heating appliances, cooking equipment, and vehicles. LPG has a very wide variety of uses, mainly used for cylinders across many different markets as an efficient fuel container in the agricultural, recreation, hospitality, calefaction, construction, sailing and fishing sectors. It can serve as fuel for cooking, central heating and to water heating and is a particularly cost-effective and efficient way to heat off-grid homes.

Biodiesel: it is an alternative fuel produced from vegetable oils and animal oil fats. It is a renewable and bio degradable fuel. It is produced from transesterification of oils and fats. The rapeseed or soya been oils are most commonly used for the production. Crops like Palm oil, sun flower oil, coconut oil can also be used. Animal fats including tallow, lard and fish oil can also be used for production.

Preparation: the process in which oils or fats react with an alcohol (methanol) to form esters and glycerol in presence of a catalyst like NaOH is called transesterification. Chemically bio diesel is alkyl esters of fatty acids.

Transesterfication:

$$\text{Lipids} + \text{Methanol} \xrightarrow{\text{NaOH}} \text{Glycerol} + \text{Methyl ester of fatty acids (Biodiesel)}$$

Advantages:

- Biodiesel is eco-friendly and renewable
- Reduces dependency on fossil fuels
- It can be used in existing diesel engines
- It improves engine life
- Decreases emission of green house gases
- It is bio degradable and non toxic.