UNIT 4

ENERGY SOURCES

A fuel is a substance which provides energy on combustion for industry and domestic purpose. The combustion is the process of oxidation that provides heat energy with light.

Example: combustion of wood, petrol and kerosene gives heat energy.

Fuel → Heat energy + Light + Combustion products (CO_2 +H_2O)

CLASSIFICATION

Type of fuel	Natural (or) primary	Artificial (or) secondary
Solid	Wood, peat, lignite, and dung	Char coal and coke
Liquid	Crude oil	Petrol and diesel
Gaseous	Natural gas	Coal gas, bio gas and water gas

CHARACTERISTICS OF GOOD FUEL:

1. It must have a high calorific value and the handling should be easy.
2. It should be economical and easily available.
3. It should be dry and should have less moisture content.
4. A fuel should have low content of non-combustible matter in the form of ash.
5. In case of solid fuel, the size should be controllable so that it can be started or stopped.
6. It should be cheap. An ideal fuel should have moderate ignition temperature.
7. It should not produce harmful products like CO_2, SO_2, H_2S and other poisonous gases.
8. Easily transport & ecofriendly

SOLID FUELS

Because of environmental hazards, trees were buried inside the earth. By the temperature, pressure and bacterial actions, they were converted into a brown black solid named coal, during thousands of years. Wood→ coal

Coal is highly carbonaceous matter and is regarded as a fossil fuel produced from large accumulations of vegetable debris and alternation of vegetable matter like plants. Under certain favorable conditions by the action of heat and pressure over millions of years. Coal is mainly composed of carbon, oxygen, hydrogen and nitrogen.

Classification of Coal:

Wood →Peat→ Lignite→ Bituminous →Anthracite

Peat: Peat is regarded as the first stage in the transformation of wood into coal. It is brown, fibrous, jelly like mass and it is un-economical fuel. Contains: 80-90% of H_2O, Composition: C =57%, O = 35%, H= 6%, ash = 2.5 to 6%.Calorific value = 5400 kcal/kg.

Lignite: (Brown coal) soft, brown, colored lowest rank coal moisture content is 20 to 60%. Composition: C = 60%, O = 20%, Calorific value = 6,500 to 7,100 k.cal/kg.

Bituminous: Bituminous coal (common coal) Black to dark colored. This coal is largely used in industries for making metallurgical coke, coal gas and for domestic heating. It has laminated structure it is sub classified based on carbon content. Composition is % of C = 78 to 90%, VM = 20 to 45%, CV = 8000 to 8500 kcal/kg.

Anthracite: Highest rank of coal. These coals have very low volatile matter, ash & moisture. This coal is very hard, dense and lustrous in appearance. % of C = 98 % has lowest volatile matter hardest, dense, lustrous. CV = 8650 to 8700 k.cal/kg.

Fuel	Moisture Content (%)	Percentage of Carbon	Calorific Value (k.cal/kg)	Main Applications
1. Wood	25	50	4000 – 4500	Domestic fuel
2. Peat	25	57	4125 – 5400	Used if deficiency of high rank coal is prevailing.
3. Lignite	20	67	6500 – 7100	Used for steam generation in thermal power plants and for the production of producer gas.
4. Bituminous	4	83	8000 – 8500	Used in making coal gas and metallurgical coke. Also used for steam generation in thermal plants and for domestic heating.
5. Anthracite	1.5	93	8650 – 8700	Used in households and for steam raising. Also used in metallurgical purposes, where no smoke and high local heat is desired.

Analysis of coal

To assess the quality of coal, the following two types of analysis are carried out:
1. Proximate analysis 2. Ultimate analysis

PROXIMATE ANALYSIS

This analysis records moisture, volatile matter, ash and fixed carbon as percentages of the original weight of the coal sample. Proximate analysis is of significance in commercial classification and industrial utilization of coal.

a. Moisture: 1 gram of coal sample is finally powdered and air dried is weighed in a silica crucible. The crucible is heated in an oven at 105-110^{0}C for one hour then taken out, cooled in a desiccators and weighed.

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

b. Volatile matter: the coal powder left in crucible (a) is then covered with a lid and placed in a muffle furnace where the temperature is maintained at 950 ± 20^{0}C for 7 minutes. The crucible is taken out, cooled and weighed. From the loss in weight after the moisture analysis, the percentage of volatile matter can be calculated.

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

c. Ash: The residual coal in the crucible (b) is then heated without lid in a muffle furnace at 700 ± 50^{0}C for 30 minutes. The crucible is taken out, cooled and weighed.

$$\% \text{ Ash} = \frac{\text{Weight of ash formed}}{\text{Weight of coal taken}} \times 100$$

d. Fixed carbon: This is reported as the difference between 100 and the sum of the percentage of moisture, volatile matter and ash.

% fixed carbon = 100 - % (moisture + volatile matter + ash)

SIGNIFICANCE OF PROXIMATE ANALYSIS:

a. Moisture: High percentage of moisture is undesirable because it increases the transport costs and reduces calorific value. Practically some percentage of moister is required because it reduces the formation of clinkers (lumps of ash formed due to its melting).coal is moistened it is introduced into the furnace which is called tempering of coal

b. Volatile matter: The presence of noncombustible gases like CO_2 and N_2 is undesirable, since they do not add to the heat value. High volatile matter containing coals give long flames, high smoke and low calorific value.

c. Ash: The presence of ash is undesirable because ash reduces the calorific value. Increases transport, handling, storage and disposal costs.

d. Fixed carbon: The presence of fixed carbon is desirable one and it helps in increasing the heating value of the fuel. Higher the % of fixed carbon greater is the calorific value.

ULTIMATE ANALYSIS:

This consists of determination of C, H, S, N and O. The ultimate analysis is essential for calculating heat balances in any process for which coal is employed as a fuel.

a. Carbon and Hydrogen determination: A known mass of coal is taken and burnt in an apparatus. The carbon changes to CO_2 and hydrogen changes to H_2O. The vapours CO_2 and H_2O are then passed through KOH and $CaCl_2$. The CO_2 is absorbed by KOH in the tube while H_2O is absorbed by $CaCl_2$. Because the absorption, the weight of KOH and $CaCl_2$ increases, this is then measured.

$C + O_2 \rightarrow CO_2$ $\qquad$ $H_2 + \frac{1}{2} O_2 \rightarrow H_2O$

12gm (44gm) (2gm) (18gm)

$2KOH + CO_2 \rightarrow K_2CO_3 + H_2O$ $\qquad$ $CaCl_2 + 7H_2O \rightarrow CaCl_2 . H_2O$

$$\text{Percentage of carbon} = \frac{\text{Increase in weight of KOH}}{\text{Weight of coal}} \times \left(\frac{12}{44}\right) \times 100$$

$$\text{Percentage of hydrogen} = \frac{\text{Increase in weight of } CaCl_2}{\text{Weight of coal}} \times \left(\frac{2}{18}\right) \times 100$$

b. Nitrogen: The estimation of nitrogen is done by Kjeldahl's method. About 1gm of finely powdered coal sample is heated with concentrated H_2SO_4 along with K_2SO_4 & $CuSO_4$ catalyst in a Kjeldahl's flask. Nitrogen in the coal is converted into $(NH_4)_2SO_4$

After the solution becomes clear i.e., when whole nitrogen is converted into ammonium sulphate, it is treated with excess of NaOH to liberate ammonia. The liberated ammonia is distilled into a measured amount of standard acid. The volume of unused acid (H_2SO_4) is then determined by titrating with NaOH. thus the amount of acid neutralized by liberated ammonia is determined from which the nitrogen present in the sample is calculated

$$N2 + H_2SO_4 \xrightarrow{K_2SO_4 \& CuSO} (NH_4)2SO4$$

$$(NH_4)_2SO_4 + 2NaOH \rightarrow 2NH_3 + Na_2SO_4 + 3H_2ONH_3 + HCl \rightarrow NH_4Cl$$

$$\text{Percentage of nitrogen} = \frac{\text{Volume of } H_2SO_4 \text{x Normality of } H_2SO_4}{\text{Weight of coal sample taken}} \text{ x } (14/1000)\text{X } 100$$

c. Sulphur: A known weight of coal is burnt completely in bomb calorimeter in a current of oxygen, wherein the sulphur present in the coal is oxidized to sulphates. This upon treatment with barium chloride precipitates the sulphate as barium sulphate. The precipitate of $BaSO_4$, is filtered, washed, dried and heated to constant weight (x gms).

$$S + O_2 \text{--------} > SO_4^{-2} \xrightarrow{BaCl2} \text{---------} > BaSO_4 + 2\ Cl^-$$

Sulphur is estimated gravimetrically in terms of $BaSO_4$

$$\text{Percentage of sulphur} = \frac{\text{Weight of } BaSO_4}{\text{Weight of coal}} \text{ x } (32/233) \text{ x } 100$$

D) Oxygen: The percentage of oxygen is determined by subtracting the sum of percentages of C, H, S, and ash from 100.

Percentage of oxygen= 100 – (percentages of C+H+N+S)

SIGNIFICANCE OF ULTIMATE ANALYSIS:

a. Carbon and Hydrogen determination: The most desirable element is carbon. The % of carbon is high the calorific value is also high. Hydrogen is not desirable one so that lesser the %of hydrogen is the better coal.

b. Nitrogen: It is least desirable in coal analysis, because it is inert gas and it is not influence inthe calorific value.

c. Sulphur: The presence of sulphur is undesirable one, because though it enhances calorificvalue but it produces harmful gases.SO_2 gets oxidized to SO3, which forms H_2SO_4, leading to corrosion.

d. Oxygen: The presence of oxygen is undesirable which causes low calorific value and lowcocking power.

Liquid fuels

Petroleum is one of the best primary liquid fuels. It is also known as crude or mineral or rock oil. Petroleum is dark-brown viscous liquid. It is a mixture of number of hydrocarbons (paraffin's, olefins, aromatics and naphthalene), nitrogen, sulphur, and oxygen containing optically active compounds along with traces of compounds of heavy metals like Fe, Co, Ni and V.

Advantages

- Higher calorific value
- No problems like ash, dust, etc.
- Transportation and storage is easy
- Control over combustion
- Less furnace spaces
- Suitable for internal combustion engine

Dis advantages: cost , greater risk fire hazardous , required special burners & special storage

Classification of crude oil: There are three types of petroleum.

1. Paraffine base type crude oil (saturated hydrocarbons from CH_4 -$C_{35}H_{72}$)
2. Asphaltic–base type crude oil (cycloparafine and naphtlenes)
3. Mixed base type: both (Paraffine base + Asphaltic–base)

REFINING OF CRUDE OIL

Crude oil obtained from the mine is not fit to be marked. It contains a lot of soluble and insoluble impurities which must be removed. Previously the purification of crude oil is done by simple fractional distillation. Further treatment of the products is done by refining. Refining can be defined as the process by which petroleum is made free of impurities, division of petroleum into different fractions having different boiling points and their further treatment to impart specific properties.

Refining of petroleum is done in different stages:

a. Removal of solid impurities: the crude oil is a mixture of solid, liquid & gaseous substances. This is allowed to stand un-disturbed for some time ,when the heavy solids settle down and centrifuged

b. Removal of water (Cottrell's process):

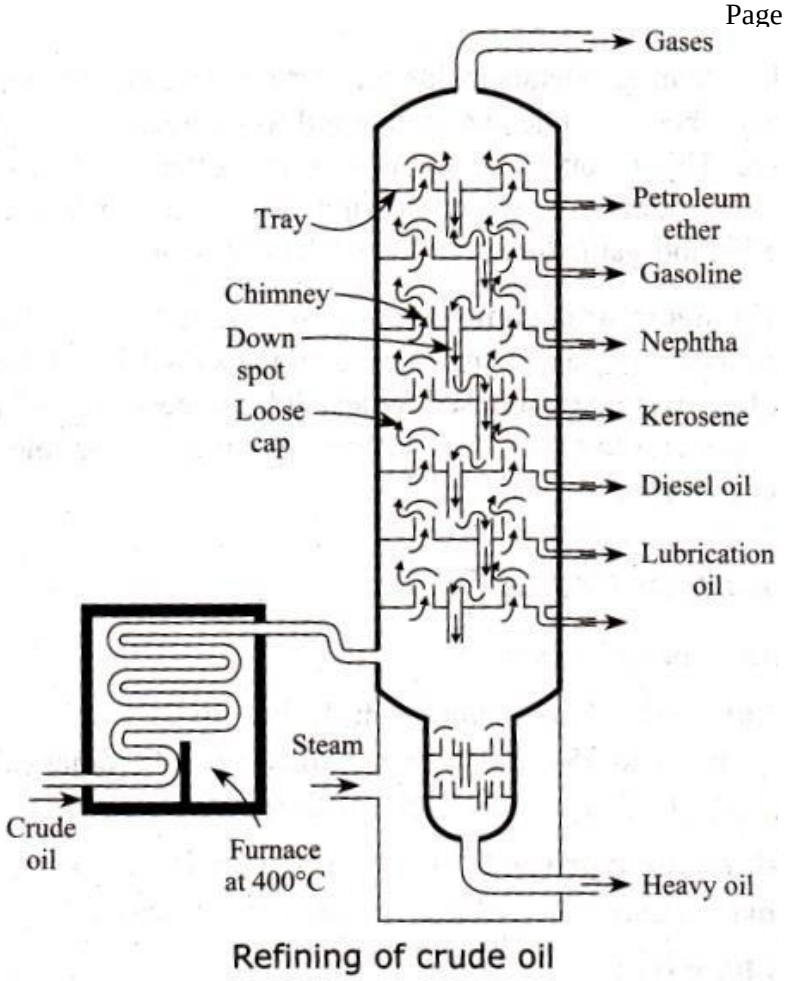
The crude oil obtained from the earth's crust is in the form of stable emulsion of oil and brine. And it is passed through highly charged electrodes get separated out from the oil

c. Removal of harmful impurities:

In order to remove sulphur compounds in the crude oil. It is treated with copper oxide. The sulphur compounds get converted to insoluble copper sulphide, which can be removed by filtration. Substances like NaCl and $MgCl_2$ it presents will corrode the refining equipment and result in scale formation. These can be removed by techniques like electrical desalting and dehydration.

d. Fractional distillation:

Heating of crude oil around 400^0C in an iron retort, produces hot vapor which is allowed to pass through fractionating column. It is a tall cylindrical tower containing a number of horizontal stainless trays at short distances and is provided with small chimney covered with loose cap. As the vapors go up they get cooled gradually and fractional condensation takes place. Higher boiling fraction condenses first later the lower boiling fractions. The constituents of each fraction and the temperature at which they are obtained is given in the table:



Refining of crude oil

S.No	Fraction name	Boiling range	Approx. Carbon Composition	Applications
1	Un condense Gases	Below 30°C	C_1-C_4	Preparation of LPG & as Fuel
2	Petrolium Ether	30 -70°C	C_5-C_7	As a solvent
3	Gasoline(or) Petrol	40 -120°C	C_8-C_9	As a motor fuel
4	Naphtha	120-180°C	C_9-C_{10}	As a solvent and Dry cleaning
5	Kerosene	180-250°C	C_{10}-C_{16}	Jet engine fuel
6	Diesel	250-320°C	C_{10}-C_{18}	Diesel engine fuel
7	Lubrication oil	320-400°C	C_{17}-C_{38}	As a lubricant
8	Heavy oil	Above 400°C	Above C_{38}	Laying roads, water proofin Substance

SECONDARY LIQUID FUELS

Only 20 % of the petrol which we were using is from petroleum fractionating column and it is called **straight run petrol**

50% of the petrol in utility is by a process called **cracking** and the remaing 30% of the petrol is synthesized from coal and water which is called **synthetic petrol**

Definition: Cracking is a decomposition of larger hydrocarbon molecules to smaller molecules(low B.pt &low MWts).

Ex. $C_{10}H_{22} \rightarrow C_5H_{12} + C_5H_{10}$
Decane Pentane Pentene

Types of cracking

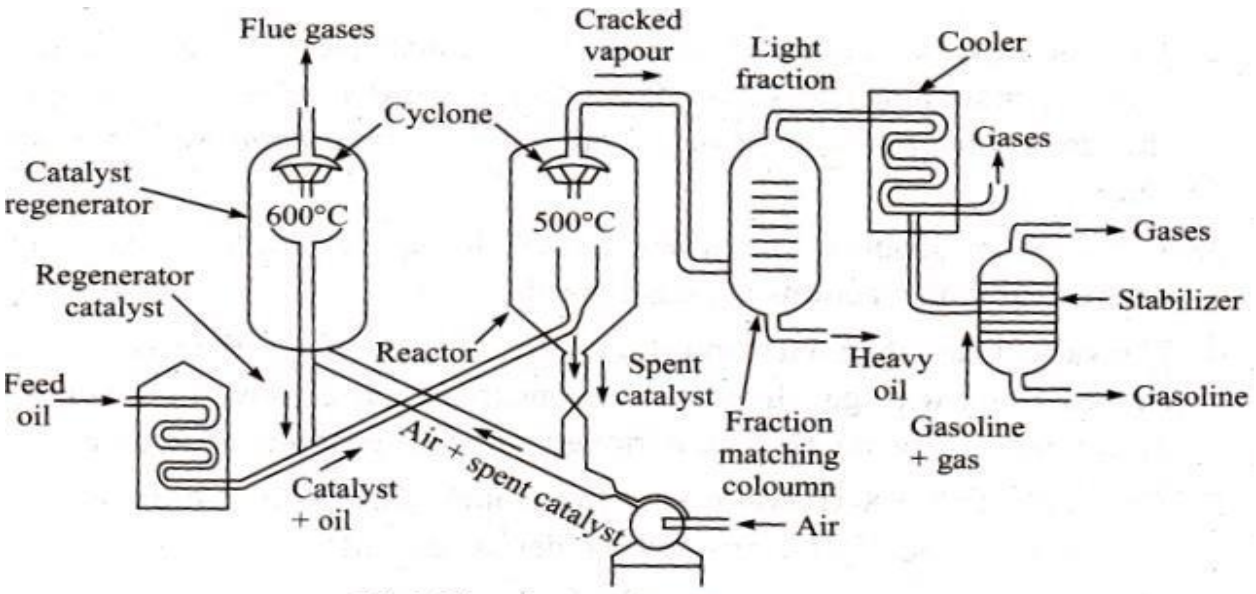
1.Thermal cracking
a.) Liquid phase thermal cracking
b) vapour phase thermal cracking

2.catlytical cracking

- Moving-bed catalytic cracking
- fixed-bed catalytic cracking

Moving-bed catalytic cracking:

- The solid catalyst is very finely powdered, so that it behaves almost as a fluid, which can be circulated in chamber move freely like a fluid. Hence this process is called *fluidised bed catalytic or moving bed catalytic cracking*
- The vapours of cracking stock mixed with fluidized catalyst is forced up into a large reactor 'bed' in which cracking of the heavier into lighter molecules occurs.
- Near thetop of the reactor, there is a centrifugal separator, which allows only the cracked oil vapours to pass on to the 'fractionating column, but retains all the catalyst powder in the reactor itself.
- The catalyst powder gradually becomes heavier, due to coating with carbon, and settles to the bottom,form where it is forced by an air blast to regenerator it maintained at 600^0C.
- In regenerator, carbon is burnt and the regenerated catalyst then flows through a stand-pipe for fixing with fresh batch of incoming cracking oil.
- At the top of the regenerator, there is a separator, which permits only gases like CO_2 to passut, but holds back catalyst particles.



Fluid-bed cracking

KNOCKING

Definition: The pre-ignition of the fuel at the compression end of the cylinder, leading to production of metallic sound (an explosive violence) is known as knocking.

In an internal combustion engine, a mixture of gasoline vapor and air is used as a fuel. After the initiation of the combustion reaction, by spark in the cylinder, the *flame should spread rapidly andsmoothly through the gaseous mixture; thereby the expanding gas drives the piston down the cylinder.*

The ratio of the original volume of fuel to the final volume after compression is called **compression ratio**.

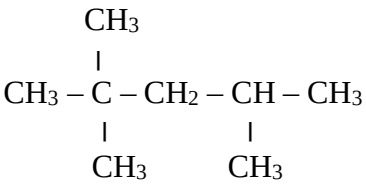
The efficiency of an internal combustion engine increases with the compression ratio, which is dependent on the nature of the constituents present in the gasoline used. The knocking results in loss of efficiency.

Some of the effects of knocking:

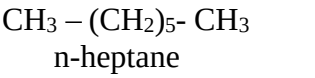
1. Carbon deposits on liners and combustion chamber.
2. Mechanical damage.
3. Increase in heat transfer.
4. Noise and roughness.
5. Decrease in power output and efficiency.
6. Pre-ignition.

OCTANE NUMBER

- The knocking characteristic of a petrol can be easily expressed by octane number.
- The anti- knocking value of n-heptane is taken as 0 (zero) because n-heptane knocks very badly. Whereas the anti-knock value of iso-octane is approximately taken as 100 because iso-octane knocks very little.
- Actually, the octane number is the percentage of iso-octane in a mixture of n-heptane and iso octane in order to matches the knocking characteristics of the fuel.
- In this way, an "80-octane" fuel is one which has the same combustion characteristics as a 80:20 mixture in isooctane and n-heptane.
- The octane number of poor fuels can be raised by the addition of extremely poisonous materials as ***Tetra ethyl lead*** $(C_2H_5)_4Pb$ & ***Diethyl-telluride*** $(C_2H_5)_2Te$



2, 2, 4- trimethyl pentane
Isooctane) octane number 100 (good fuel)



n-heptane
octane number zero (bad fuel)

CETANE NUMBER

- The knocking characteristics of ***diesel*** oil are expressed in terms of cetane number.
- Cetane ($C_{16}H_{34}$) is a saturated hydrocarbon which has a very short ignition lag as compared to any commercial diesel fuel. Hence, its cetane number is taken as 100.
- On the contrary, Alpha-methyl naphthalene. $C_{11}H_{10}$ has a very long ignition lag as compared to any commercial diesel oil. Hence its cetane number is taken zero.
- Then the cetane number of diesel oil is defined as the percentage by volume of cetane in a mixture of cetane and Alpha-methyl naphthalene which exactly matches in its knocking characteristics with the oil under test.
- Cetane number, it can indicate the purity of diesel oil. The percentage of cetane in a mixture of cetane and n-hexadecane which has same ignition characteristics as the diesel fuel under test is certain number.

Cetane (n-hexadecane)
Cetane number = 100 (good fuel)

2-methyl naphthalene
Cetane number = 0 (bad fuel)

Lead petrol: The variety of petrol in which tetra ethyl lead is added, it is leaded petrol

Advantages:

Usually petrol with low octane number is not good quality petrol. It often knocks (produces huge noise due to improper combustion). As a result of knocking, petrol is wasted; the energy produced cannot be used in a proper way.

When tetra ethyl lead is added, it prevents knocking, there by saves money and energy. Usually 1 to 1.5 ml of TEL $Pb(C_2H_5)_4$ is added per 1lit of petrol.

The mechanism of action is as follows:

First TEL will be transformed into finely divided particles of PbO which looks like a cloud. This takes place in the cylinder. Then the PbO particles react with hydrocarbon peroxide molecules formed, thus slowing down the oxidation process and prevent early detonation. Thus either knocking may be stopped or greatly reduced.

Disadvantages:

Deposits of PbO are harmful to engine. So PbO must be eliminated from the engine. For this purpose, little amount of ethylene dibromide is added to petrol. It converts the harmful PbO to volatile $PbBr_2$ and eliminated through exhaust. Presence of any sulphur compounds reduces the efficiency of TEL.

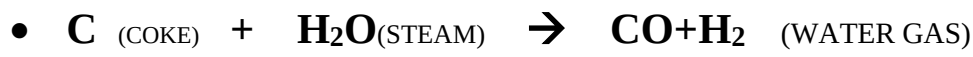
SYNTHETIC PETROL

Due to increase the usage of petrol, so the importance came for preparation synthetic methods of petrol. The important processes commonly used for synthesis of petrol are:

1 . Fischer-tropsch method
2. Bergius process(hydrogenation of coal)
3. polymerization

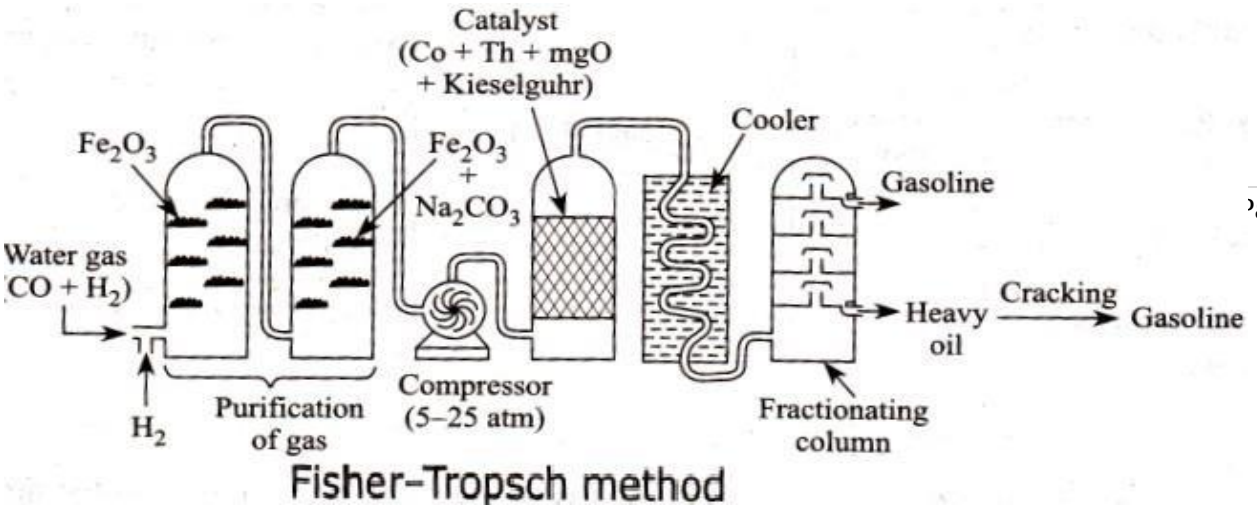
1. **FISCHER-TROPSCH METHOD:**

- This method was developed by Franz Fischer & Hans Tropsch (German scientists).
- The raw material is the hard coke which is converted into water gas ($CO + H_2$) by passing steam over red-hot coke. (1200^OC)



- this water gas is purified with Fe_2O_3, Na_2CO_3 & hydrogen
- This mixture after the removal of impurities is heated in afurnace maintained at a temperature of 200 – 300^0C and a pressure of 30 atm.
- The mixture is then led to converter containing the catalyst consisting 200 arts of keisalghr, 100arts of Cobalt, 5 arts of thoria, 8 parts of magnesia

$$nCO + (2n + 1)\, H_2 \rightarrow C_nH_{2n+2} + nH_2O$$
$$nCO + 2n\, H_2 \rightarrow C_nH_{2n} + nH_2O.$$



Fisher–Tropsch method

- The reactions taking place in the converter exothermic, so this mixture from converter passing through cooler
- The products are then passed to a fractionating column and separated in to different fractions such as heavy oil, kerosine, gasoline. the heavy oil can be reused for cracking to get more gasoline
- The product formed depends upon the catalyst used.
- A cobalt catalyst gives more olefins. Iron oxide with K_2CO_3 as promoter gives heavier hydrocarbons than those obtained from iron oxide and Na_2CO_3.
- Mixed catalysts such as cobalt magnesia are used to produce high-grade diesel fuel from the enriched water gas.

GASEOUS FUELS

THE NATURAL GAS:

- It is mainly composed of methane and small quantities of ethane along with other hydrocarbons.
- If thelower hydrocarbons are present the gas is called dry gas or lean gas,
- but if the hydrocarbons having the higher molecular weights are present the gas is known as rich gas or wet gas.
- It is also known by the name of marsh gas as a major portion of it is contributed by methane.

Composition of natural gas:

Methane (CH_4) – 88.5% Ethane (C_2H_6) – 5.5%

Propane (C_3H_8) – 3.7% Butane (C_4H_{10}) –

1.8%Pentane, H_2, CO, CO_2 and higher hydrocarbons – 0.5%.

The calorific value of natural gas varies from 8000 – 14000 k.cal/m^3.

Applications of natural gas:

1. It is also used for manufacturing a number of chemicals like carbon black, methanol.
2. Methane on microbiological fermentation give synthetic proteins used as animal feed.
3. It is also used for generation of electricity in fuel cells.
4. Natural gas is also used as a source of H_2.

LPG (LIQUEFIED PETROLEUM GAS):

- The main composition of LPG is n-butane (27%), isobutene (25%), butene (45%) and propene propane 3%.
- The hydrocarbons are in gaseous state at room temperature.
- LPG has special odour due to the presence of organic sulphides which are added specially for safety measure.

Characteristics of LPG:

- It has high calorific value 27800 kcal/cm^3.
- It causes least pollution.
- It gives moderate heat which is very good for cooking.
- Its storage is very simple. It is colure less.
- It neither gives smoke nor ash content.
- It is cheaper than gasoline and hence used as fuel in auto vehicles also.
- It is dangerous when leakage is there.

Applications of LPG:

- It is used as domestic fuel.
- It is used as industrial fuel.
- It is used as fuel for motor vehicles.

CNG (COMPRESSED NATURAL GAS):

The natural gas contains mainly CH_4.When natural gas compressed at high pressure (1000 atm) orcooled to -160^{0}C, it is converted to CNG. It is stored in cylinder made steel.

CH4=85% , ETHANE = 5%, PROPANE =10%

Characteristics of CNG:

It is light gaseous fuel, it mixes with air easily. It has a high auto ignition temperature. It is havingof calorific value is 900KJ/mole(2500 kcal/kg)

Applications of CNG:

- Due to higher temperature of ignition, CNG is better fuel than petrol and diesel.
- Operating cost of CNG is less. It releases least pollutants like CO and unburnt hydrocarbons.
- No anti-knocking agent is required as it has octane number.

Combustion

Combustion:
Combustion is a process of combination of an element with oxygen by liberation of heat. It is an exothermic reaction.

$$C + O_2 \rightarrow CO2 - \Delta H = \text{heat}$$

Calorific value: The amount of heat produced by the combustion of unit mass (or) unit volume of a fuel is called the Calorific value of the fuel. There are different units for measuring the quantity of heat. They are:
1. Calorie
2. Kilocalorie
3. British thermal unit (B.T.U)
4. Centigrade heat unit (C.H.U)

Relationship among all the above units of heat: 1 kcal = 1000 cal = 3.968 BTU = 2.2 CHU
Joule is also a unit of energy, 1cal = 4.18 joule

➢ HIGH CALORIFIC VALUE (OR) GROSS CALORIFIC VALUE:

It is defined as the amount of heat energy produced by the combustion of unit mass (or) unit volume of a fuel is when the combustion products are allowed to cool at the room temperature. Generally, during combustion, water vapor and CO_2 are formed. As the products of combustion are cooled to room temperature, the steam gets condensed into water and the latent heat is evolved.

Thus the latent heat of condensation of steam, so liberated, is included in the gross calorific value.

➢ LOW CALORIFIC VALUE (OR) NET CALORIFIC VALUE:

It is defined as the amount of heat produced, when unit mass or unit volume of the fuel is burnt completely and the combustion products are allowed to escape. Net calorific value is the gross calorific value excluding the latent heat of condensation of water.

Relationship between HCV and LCV: $H_2 + 1/2O_2 \rightarrow H_2O$

If hydrogen is present in a fuel, the above mentioned chemical reaction will take place and 2 grams of hydrogen will produce 18 grams of H_2O (or) 1 gram of hydrogen will produce 9 gramsof H_2O. If x grams of hydrogen is present in a fuel, it will produce 9 grams of water and 9 grams of water vapour that will release 9x*L cal heat on cooling.

LCV = HCV – Latent heat of water vapour formed
LCV = HCV – 9 × H/100 × 587 kcal/kg
LCV = HCV –0.0 9 × H × 587 kcal/kg

Determination of Calorific Value By Dulong's Formula

In this formula the higher calorific value of the fuel is the calorific value of each of the components. Secondly 8 parts by weight of O_2 combine with one part by weight of oxygen. So if oxygen is present, it must be present6 in the combined form with hydrogen as water thereby decreasing the amount of hydrogen available for combustion by O/8 then the formula is:

$$HCV = 1/100[8080\ C + 34500(H-O/8) + 2240\ S]$$

Where C, H, O, S are the percentages of carbon, Hydrogen, Oxygen and Sulphur respectively, as determined by the ultimate analysis of fuels. The calorific values of the components of the fuels are given below:

Constituent	Calorific value(cal/gram)
Carbon	8080
Hydrogen	34500
Sulphur	2240

➢ BIODIESEL PRODUCTION PROCESS

- Biodiesel is produced from vegetable oils or animal fats and an alcohol, through a transesterification reaction.
- This chemical reaction converts an ester (vegetable oil or animal fat) into a mixture of esters of the fatty acids that makes up the oil (or fat).
- Biodiesel is obtained from the purification of the mixture of fatty acid methyl esters (FAME).
- A catalyst is used to accelerate the reaction.
- In order to understand the chemical process, we must know the chemistry of esterification and transesterification.

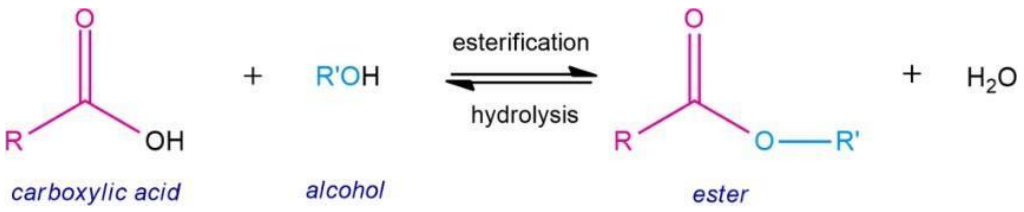
Chemistry of Esterification

- It is the general name for a chemical reaction in which two reactants (typically an alcohol and an acid) form an ester as the reaction product.

  reaction:

  $$CH_3\ COOH + CH_3\ CH_2\ OH \text{ ====> } CH_3COOCH_2CH_3 + H_2O$$

- The esterification reaction may also be written as reflected by.



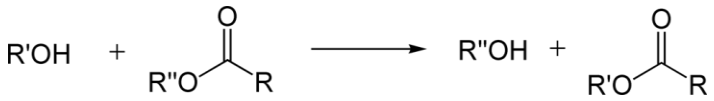
Esterification reaction (R, R' different alkyle groups).

- **Chemistry of Transesterification**
  - ✓ In organic chemistry, transesterification is the process of exchanging the organic group R″ of an ester with the organic group R′ of an alcohol.
  - ✓ These reactions are often catalyzed by the addition of an acid or base catalyst.
  - ✓ The reaction can also be accomplished with the help of enzymes (biocatalysts)

particularly lipases.

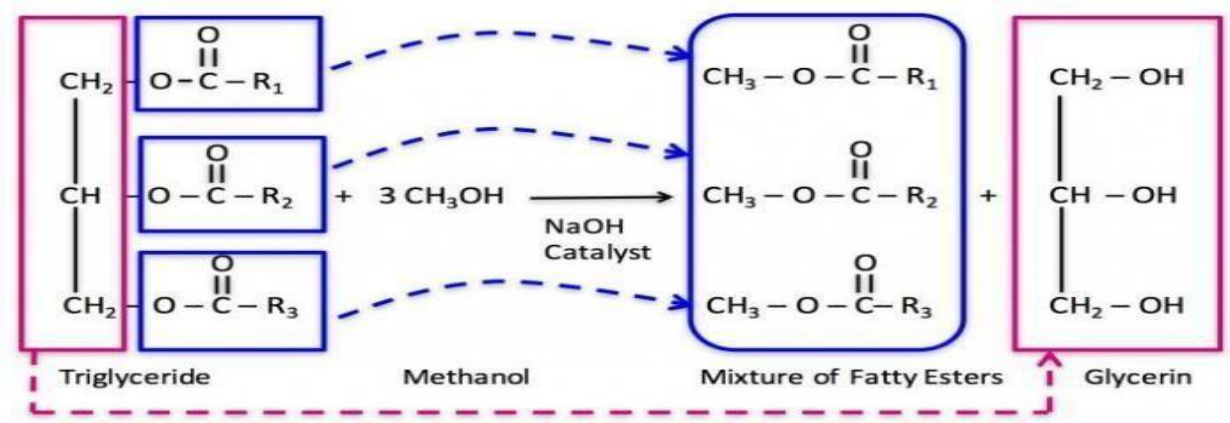
- ✓ A generic transesterification reaction has been reflected by the reaction (1) and

$$R'OH + R''COOR \underset{}{\overset{Catalyst}{\rightleftharpoons}} R''OH + R'COOR$$



A generic Transesterification reaction.

When methanol is the alcohol used in the transesterification process, the product ofthe reaction is a mixture of methyl esters (fatty esters); as shown in



Transesterification with methyl alcohol.

- ✓ In consequence, once the chemical reaction is completed and the two phases (mix of esters and glycerin) are separated, the mix of methyl esters must be purified to reduce the concentration of contaminants to acceptable levels.
- ✓ These include remnants (few left) of catalyst, water and methanol; the latter is usually mixed in excess proportion with the raw materials in order to achieve higher conversion efficiency in the transesterification reaction.

ADVANTAGES BIODIESEL:

- Easy to use: No vehicle modification or any fueling equipment needed.
- Power, Performance and Economy: Proven power generation, performance and cost efficiency madebiodiesel a useful fuel.
- Effect on environment: Biodiesel is helping in reducing pollution and improve health by lowering theemission of CO2 which reduces the effect of global warming.
- Biodiesel reduces the use of foreign oils. Biodiesel is safer to handle because it is less toxic and easyto store than petroleum.

Essay Questions

1. Write down Proximate and Ultimate analysis of coal? And its significance
2. What is calorific value? Explain solid, liquid, gaseous fuels?
3. Explain Fischer Tropsch Process of manufacture of synthetic Petrol?
4. Write refining of petroleum?
5. What is calorific value Explain how to estimate HCV & LCV using dulongs formula.
6. What is cracking? Explain moving bed cracking
7. Explain knocking, cetane, octane number
8. Write a short note on refining of petroleum
9. What is biodiesel? explain transesterification process and advantages of biodiesel

Short Answer Questions

1. Define a fuel.
2. What is meant by calorific value of a fuel?
3. What is ignition temperature?
4. What is octane number?
5. Name the highest ranking coal.
6. What is cracking of petroleum?
7. What is flue gas?
8. What is meant by reforming?
9. What are petrochemicals?
10. Why gaseous fuels are more advantageous than solid fuels?
11. What is cat-cracker?
12. Why natural gas is called a fossil fuel?
13. How do you analyze CO_2 and H_2O produced during combustion of a fuel sample?
14. What is the function of ethyl bromide added to petrol?
15. Distinguish between gross and net calorific value of a fuel.

Multiple Choice Questions

1. Which of the following fuels possesses the maximum calorific value? **[d]**

(a) C=84%, H=6%, S=4%, and O=6% (b) C=84%, H=12%, S=1%, O=1%(c) C=90%, H=5%, S=2%, O=3% (d) C=95%, H=2%, S=1%, and O=2%

2. A good fuel should possess: **[d]**

(a) High ignition temperature (b) Moderate ignition temperature
(c) High calorific value (d) Both B & C

3. Which of the following statements is true. **[d]**

(a) Coke possesses better strength than coal.
(b) Coke burns with a long flame. (c) Coke burns with short flame
(d) Sulfur content of cokes is higher than that of coal from which it is obtained.

4. Which of the following fuel gases possess the highest calorific value. **[c]**
(a) Water gas (b) Coal gas (c) Producer gas (d) Natural gas

5. Petro chemicals can be used to prepare **[c]**

(a) PVC plastics (b) Polystyrene plastics (c) Terylene fibres (d) None of the above

6. The maximum temperature reached, when the coal is completely burnt in the theoretical amount of air is called

[c]

(a) Fusion temperature (b) Calorific intensity (c) Ignition temperature (d)None of above

7. Bomb calorimeter is used for determining the calorific value of **[a]**

(a) Solid fuel (b) Liquid fuel (c) Gaseous fuel (d) Both (a) & (b)

8. Bomb calorimeter is used to determine **[b]**

(a) HCV at constant pressure (b) LCV at constant pressure
(c) HCV at constant volume (d) LCV at constant volume

9. Gas with least calorific value is **[b]**

(a) Coal gas (b) Water gas (c) Producer gas (d) Natural gas

10. Main constituent of natural gas is **[b]**

(a) Carbonmonoxide (b) Methane (c) Hydrogen (d) Ethane

11. A knocking sound is produced in the internal combustion engine, when the fuel **[b]**

(a) Burns slowly (b) Burns fast
(c) Contains some water (d) Is contaminated with lubricating oil.

12. Cracking is **[b]**

(a) Somewhat similar to polymerization
(b) Conversion of long-chain hydrocarbons to shorter ones
(c) The production of unsaturated molecules from saturated ones
(d) Distillation of crude oil to obtain kerosene

13. Composing of producer gas is **[b]**

(a) CO+Nitrogen (b) CO+Hydrogen (c) CO+Methane (d) Methane+Hydrogen

14. Petrol is a mixture mainly of **[d]**
(a) Alkenes (b) Alkanes (c) Alkynes (d) Aromatic hydrocarbons

Fill in the blanks

1. The calorific value of coke is generally **higher** than coal.
2. The compound with octane number 100 is **iso-octane**.
3. A good fuel should possess **moderate** ignition temperature.
4. **Petroleum** is the only primary liquid fuel in nature.
5. **HCV** calorific value includes latent heat of steam.
6. A good fuel should possess **less** moisture content.

7. The fuels which possess highest thermal efficiency are **gaseous**.

8. One KCal/Kg is equal to **1.8 B.Th.U/lb**.
9. Oxygen content **decreases** the calorific value.
10. The calorific value of coke is generally **higher** than coal.
11. During petroleum cracking the products obtained have **lower** boiling points.
12. Higher the octane rating of gasoline, **lesser** is its tendency for knocking.
13. The compound with octane number 100 is **iso – octane**.
14. A good fuel should possess **moderate** ignition temperature.
15. The process of separation of various fractions of petroleum is known as **fractional distilan.**
16. **Petroleum** is the only primary liquid fuel in nature.
17. **Higher** calorific value includes latent heat of steam.
18. The SI unit for expressing the calorific value of a solid fuel is **KJ / Kg** .
19. A good fuel should possess **low** moisture content.
20. **Solid fuels** fuel which possess highest thermal combustion engines.
21. The fuels which possess highest thermal efficiency are **gaseous**.
22. An example of primary gaseous fuel is **natural gas**.

The End