UNIT-4 Energy Resources

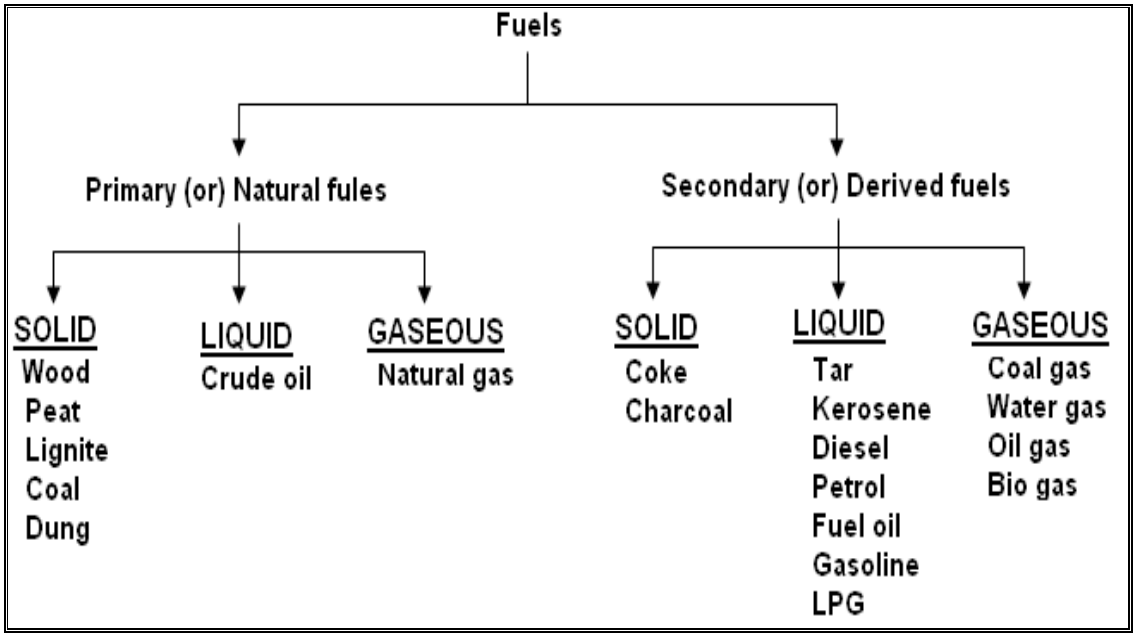
Φ Define a Fuel and Explain the classification of fuels with examples?

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

$$Fuel + O_2 \rightarrow \text{Pr}oducts + Heat$$

Classification of fuels:

- ★ On the basis of occurrence fuels are classified into primary and secondary.
- ★ Again each one is divided into three types based on their physical state.
- ★ Primary fuels are found in nature. Secondary fuels are produced from primary fuels



Φ What are the characteristics of good fuel (or) Ideal fuel?

While selecting an ideal fuel for domestic or industrial purpose we should keep in mind that the fuel selected must possess the following characteristic properties.

1) It should possess high calorific value.
2) It should have proper ignition temperature. The ignition temperature of the fuel should neither be too low nor too high.
3) It should not produce poisonous products during combustion. In other words, it should not cause pollution o combustion.
4) It should have moderate rate of combustion.
5) Combustion should be easily controllable i.e., combustion of fuel should be easy to start or stop as and when required.
6) It should not leave behind much ash on combustion.
7) It should be easily available in plenty.
8) It should have low moisture content.
9) It should be cheap.
10) It should be easy to handle and transport.

Φ Discuss comparison between solid, liquid and gaseous fuels?

Solid fuel	Liquid fuel	Gaseous fuel
1. Slow combustion and not easy to control it	Quick combustion and can be controlled	Combustion is rapid and burning can be controlled
2. Transportation is difficult	Transportation is easy through pipelines	Transportation is easy through pipe lines and containers
3. Storage is safe	There is risk in storing	There is greatest risk in storing
4. Calorific value is comparatively low	Calorific value is comparatively higher	Calorific value is highest
5. Cannot be used in internal combustion engines	Can be used in internal combustion engines	Can be used in internal combustion engines to lesser extent
6. On burning ash and more smoke are produced.	No ash is produced but Some flue gases are produced	No ash and no smoke are produced
7. More air pollution	Less air pollution	Least air pollution

Calorific Value:

❖ **What is calorific value? Give their units?**

Calorific value: It is defined as the total amount of heat liberated, when unit mass or unit volume of the fuel is completely burnt in air or oxygen.

Units of heat:-

a) Calorie:- The amount of heat required to increase the temperature of 1 gm of water through one degree centigrade.

b) Kilocalorie:- It is equal to 1000 calories. The quantity of heat required to rise the temperature of 1 Kg of water through one degree centigrade.

1 K.cal = 1000 cals

c) British thermal unit (B.Th.U.):- The quantity of heat required to rise the temperature of 1 pound of water through one degree Farenheit.

1 B.Th.U = 252 cals = 0.252 K.cal

d) Centigrade heat unit (C.H.U):- The quantity of heat required to rise the temperature of one pound of water through one degree centigrade.

1 K. cal = 3.968 B.Th.U = 2.2 C.H.U

For solids or liquid fuel: Calorie/gm (cal/gm) (or) Kilocalorie/Kg (K.cal/Kg) (or) B.Th.U/lb

For gaseous fuels: Kilocalorie/cubic meter ($K.cal/m^3$) (or) $B.Th.U/ft^3$

❖ **Define HCV & LCV. Give relationship between HCV & LCV.**

HCV: [Higher Calorific Value]: It is defined as the total amount of heat liberated, when unit mass or unit volume of the fuel is completely burnt and the products of combustion are allowed to cool to room temperature.

Hydrogen is present in almost all the fuels. During determination of calorific value, hydrogen is converted into steam. Higher calorific value includes the latent heat of condensation of steam. HCV is also called Gross Calorific Value. [GCV].

LCV: [Lower Calorific Value]: It is defined as the total amount of heat liberated, when unit mass or unit volume of the fuel is completely burnt and the products of combustion are allowed to escape out into atmosphere.

LCV is also called Net Calorific Value [NCV].

Relationship between HCV & LCV:

LCV = HCV – latent heat of water vapour formed

Since 1 part by mass of hydrogen produces 9 parts by mass of water.

Hence LCV = HCV – (mass of hydrogen x 9 x latent heat of steam)

$$LCV = HCV - (0.09\ H \times 587)$$

Where, H is % of Hydrogen

Latent heat of steam = 587 K.cal/Kg

❖ **What is Dulongs formula? Derive an expression for theoretical calculation of Calorific value of fuel?**

According to Dulong, the calorific value of fuel is the sum of the calorific values of all the elements present.

The calorific values of different elements are:

The calorific value of Carbon = 8080 cal/g

The calorific value of Hydrogen = 34500 cal/g

The calorific value of Sulphur = 2240 cal/g

The oxygen, if present in fuel, is assumed to be present in combined form with hydrogen, i.e., in the form

of fixed hydrogen [H 2 O].

The amount of hydrogen available for combustion = Total hydrogen – fixed hydrogen

Dulong's formula for calorific value from the chemical composition of a fuel is:

$$HCV = \frac{1}{100}\left\{ 8080\,(C) + 34500\left(H - \frac{O}{8}\right) + 2240\,(S) \right\}$$

LIQUID FUELS:

❖ **What are advantages and disadvantages of liquid fuels?**

Advantages:

1) They posses higher calorific value per unit mass than solid fuels.
2) They burn without dust, ash, clinkers, etc.
3) Their firing is easier and also fire can be extinguished easily by stopping liquid fuel supply.
4) They are easy to transport through pipes.
5) They can be stored indefinitely without any loss.
6) They are clean in use and economic to handle.

Disadvantages:

1) The cost of liquid fuel is relatively much higher as compared to solid fuel.
2) Costly special storage tanks are required for storing liquid fuels.
3) There is a greater risk of five hazards, particularly, in case of highly inflammable and volatile liquid fuels. They give bad odour.

❖ Explain about Refining of crude oil (or) Petroleum:

- The crude oil is separated into various fractions by fractional distillation and finally converted into desired specific products.
- The process is called "refining of crude oil" and the plants set up for the purpose, are called the oil refineries.
- The process of refining involves the following three steps:

Step-1:- Separation of water (Cottrell's process):

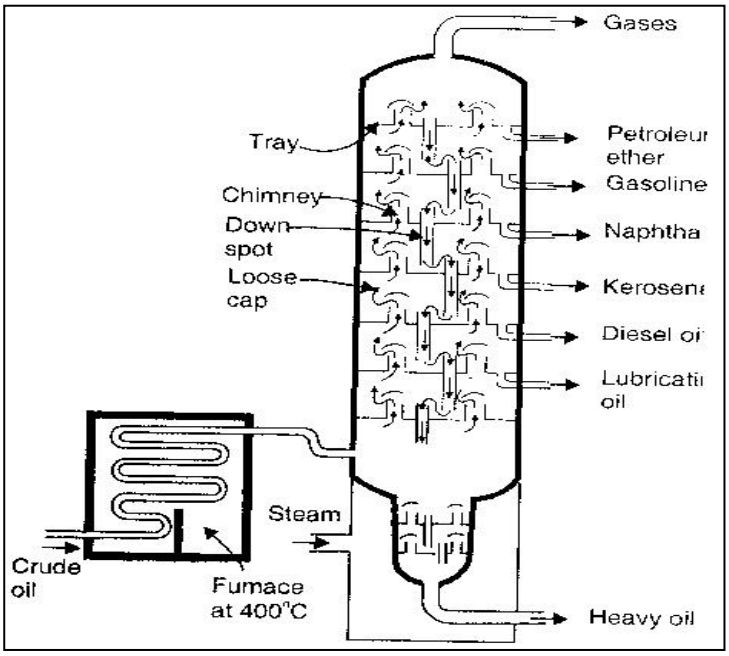
- The crude oil is in the form of stable emulsion of oil and salt water.
- Water is separated from oil by Cottrell's process.
- First the emulsified water along with salts dissolved, is removed by passing the crude oil between highly charged electrodes.
- The colloidal water droplets unite on positive electrode to form large drops which separate from oil.

Step-2:- Removal of harmful sulphur compounds:

- In this step, the oil is treated with copper oxide.
- Sulphur and its compounds are converted into solid copper sulphides.

Step-3:- Fractional distillation:

- The crude oil is then heated to about 400^{o}C in an iron retort, whereby all volatile constituents, except the residue are evaporated.
- The hot vapours are then passed up a "*fractionating column*", which is a tall cylindrical tower 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 vapours go up, they become gradually cooled and different products are obtained at different heights of the column.



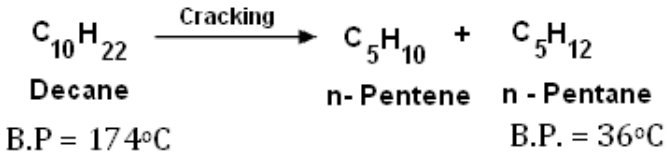
Various fractions with boiling range, approximate composition and uses :

Name of fraction	**Boiling range (°C)**	**Approximate Composition in terms of hydrocarbons containing C-atoms**	**Use**
Uncondensed gases	Below 30	$C_1 - C_4$	As domestic and industrial fuel under the name LPG
Petroleum ether	30 – 70	$C_5 - C_7$	As a Solvent
Gasoline or petrol	40 – 120	$C_5 - C_9$	Fuel for IC engines, Dry Cleaning solvent
Naphtha	120 – 180	$C_9 - C_{10}$	As solvent for paints and varnishes
Kerosene oil	180 – 250	$C_{10} - C_{16}$	Fuel for stoves, jet engine fuel and for preparing lab gas
Diesel oil	250 – 320	$C_{15} - C_{18}$	Diesel engine fuel
Heavy oil	320 – 400	$C_{17} - C_{30}$	Fuel for ships and for conversion to gasoline by cracking.

Cracking

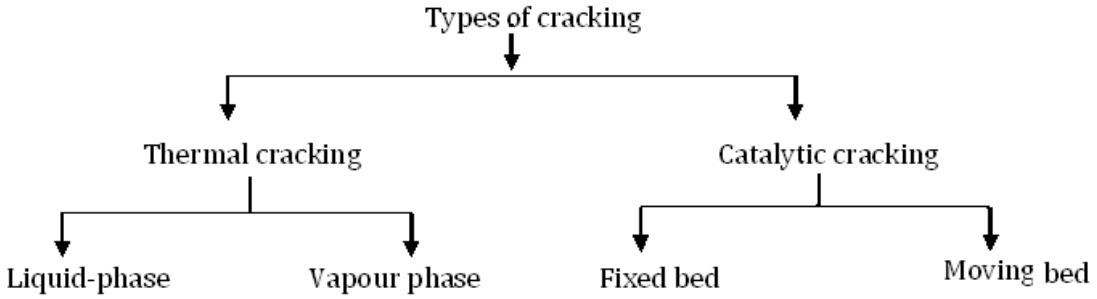
❖ **Write a note on Cracking:**

Cracking is defined as the decomposition of high molecular weight hydrocarbons of high boiling points into simpler, lower molecular weight hydrocarbons of low boiling points.



Importance:

- ✓ Of all the fractions obtained by fractionation of petroleum, gasoline has the highest demand as a motor fuel. It is called straight run gasoline.
- ✓ Also the quality of so-called 'straight-run' gasoline is not so good.
- ✓ Hence, it is used only after suitable blending.
- ✓ For instance, the petrol made by cracking has far better characteristics (as far as the IC engine is concerned) than 'straight-run' petrol.



Thermal cracking:

- ✓ When the heavy oils are subjected to high temperature and pressure in the absence of catalyst, it is called thermal cracking.
- ✓ In thermal cracking, the bigger hydrocarbon molecules break down to give smaller molecules of the paraffin, olefins plus some hydrogen.
- ✓ It is of two types' viz. liquid and vapour phase thermal cracking.

A comparative account of these two is given in the following table.

Catalytic cracking:

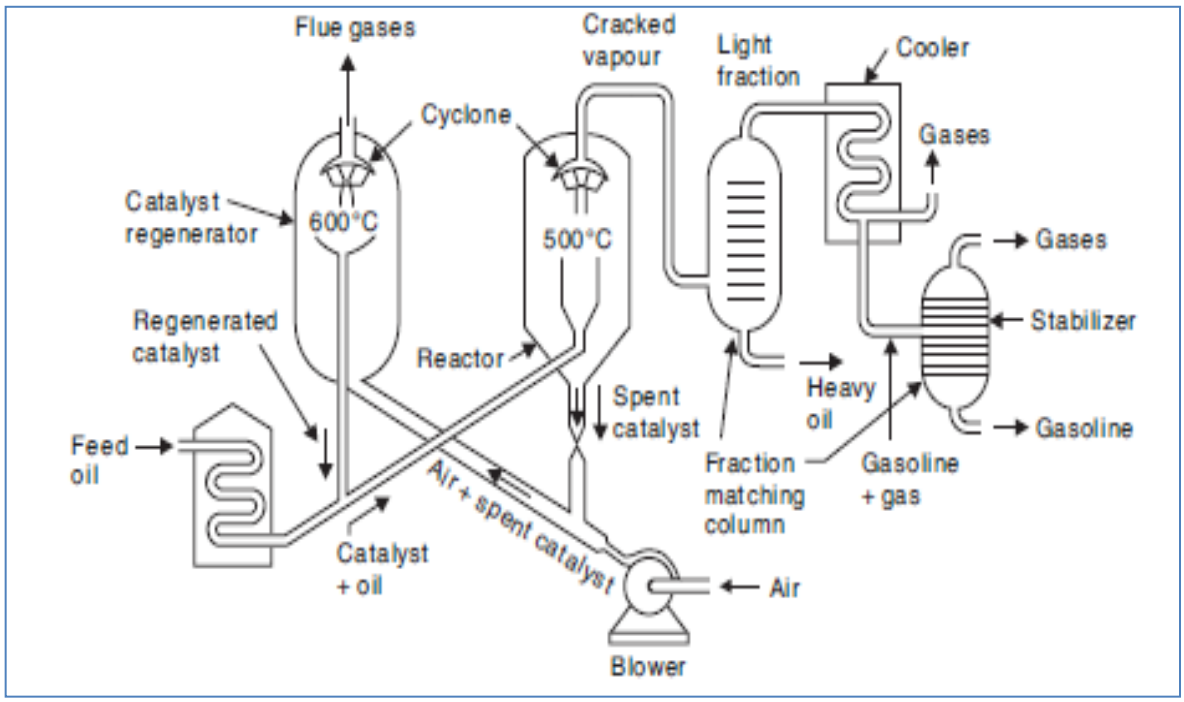
- ⮝ The quality and quantity of gasoline produced by cracking can be greatly improved by using a suitable catalyst like aluminium silicate, $Al_2(SiO_3)_3$ or alumina, Al_2O_3.
- ⮝ Catalytic cracking requires much lower temperatures and pressures compared to thermal cracking.
- ⮝ There are two types of catalytic cracking, viz. Fixed bed and Moving bed catalytic cracking.

❖ **Explain with a neat diagram Moving bed catalytic cracking?**

- ➢ In moving bed catalytic cracking, the feed oil is first passed through a preheater.
- ➢ The pre-heated oil vapours along with very finely powdered catalyst are then passed in a reactor which is maintained at a temperature of 500°C for catalytic cracking.
- ➢ The cracked oil vapours are then passed to the fractionating column where heavy oil is separated.
- ➢ The vapours are then passed through the cooler where gasoline condenses along with some gases.
- ➢ This is then sent to a stabilizer where the dissolved gases are removed and pure gasoline is recovered.

- The main components along with their functions are discussed with the help of the figure.

1. Cyclone allows only the cracked oil vapours to pass on to the 'fractionating column', but retains all the catalyst powder in the reactor itself.
2. The catalyst powder gradually becomes heavier, due to coating with carbon, and settles to the bottom, from where it is forced by an air blast to regenerator (maintained at 600^{o}C).
3. In regenerator, carbon is burnt and the regenerated catalyst then flows through stand-pipe for mixing with fresh batch of incoming cracking oil.



❖ **What are the Advantages of catalytic cracking over thermal cracking?**

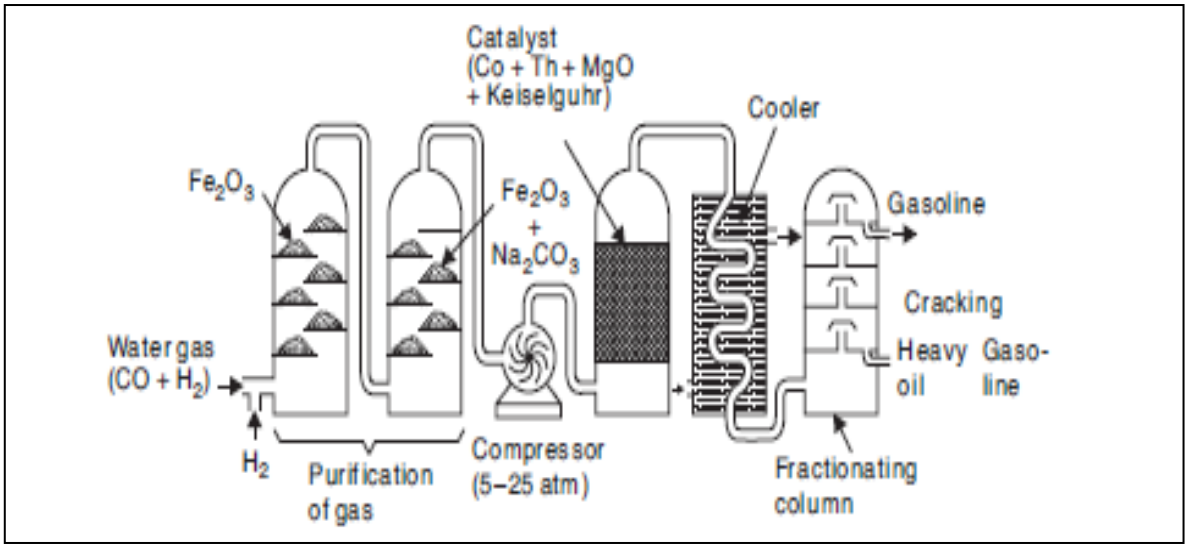
Catalytic cracking has a number of advantages:

1. The production cost is very less since high temperatures and high pressures are not needed.
2. The yield of petrol is higher.
3. The quality of petrol produced is better.
4. No external fuel is necessary for cracking. The heat for cracking is derived by burning the carbon deposited on the catalyst.
5. The product contains less sulphur compounds.
6. The percentage of gum and gum forming compounds is very low.

The octane number of cracked gasoline is higher compared to straight-run gasoline. It is due to presence of branched paraffins and aromatic hydrocarbons in cracked gasoline.

❖ **Discuss Fischer-Tropsch method of manufacture of Synthetic Petrol?**

Water gas (CO+H 2), produced by passing steam over preheated (at 1200 C) hard coke, is mixed with hydrogen. The gas is purified by passing through FeO (to remove H2S)and then into a mixture of Fe2O3 + Na2CO3 (to remove organic sulphur compounds). The purified gas is compressed to pressure of 30 atmospheres and then led through a convertor containing a catalyst, which is a mixture of 100 parts of cobalt, 5 parts of thoria, 8 parts of magnesia, and 200 parts of keiselguhar-earth, maintained at about 200-300 ° C. A mixture of saturated and unsaturated hydrocarbons results: The reaction is exothermic as such the hot gaseous mixture is led to a cooler, where a liquid resembling crude oil is obtained. The crude oil thus obtained is then fractionated to yield: (i) gasoline, and (ii) high- boiling heavy oil. The heavy oil is reused for cracking to get more gasoline.



KNOCKING

- ✓ The characteristic rattling sound produced in internal combustion engine due to immature ignition is known as knocking.
- ✓ This situation occurs when compression ratio exceeds certain limit.
- ✓ Fuel mixture is heated to beyond ignition temperature which leads prior combustion than the sparking ignition.

Influence of chemical structure on fuel knocking:

- ★ As the length of the carbon chain increase, knocking tendency increases.
  Ex: n- butane < n – pentane < n – hexane < n – heptane
- ★ Straight chain paraffins have more knocking property than branched chain alkanes.
  Ex: 2, 2 – dimethyl pentane < 2- methyl hexane < n- heptane
- ★ Aromatic compounds like benzene and toluene have poor knocking property.
- ★ In general, the order of knocking property of various compounds is
  Aromatic < Cyclo paraffins < Olefins < Branched alkanes < Straight chain alkanes.

16) Explain about Petrol Knocking : [Gasoline knocking]:

The performance of motor car is measured in terms of Km/L of petrol, which depends on the quality of the fuel.

Important method of obtaining more power from petrol is increasing the compression ratio of the engine.

Compression ratio of engine = Intial volume of petrol and air mixture sucked into cylinder / Final volume of petrol and air mixture after compression.

Increase in the compression ratio of the engine, increases the efficiency of the engine. Knocking is defined as the production of shock wave in an IC engine due to explosive combustion of mixture of petrol and air which increases compression ratio beyond a certain value leading to rattle sound.

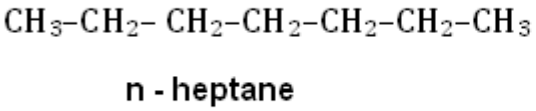
17) Explain about Diesel knocking?

Knocking in diesel engine occur due to ignition delay which is caused by the chemical nature of hydrocarbons in diesel i.e; straight chain hydrocarbons have shorter ignition delay than branched and aromatics hydrocarbons.

Ignition delay is caused because time is required for vapourization of fuel and raising the temperature of the vapour to its ignition temperature i.e; accumulation of of fuel in the engine which leads to explosive combustion. This is called diesel knocking.

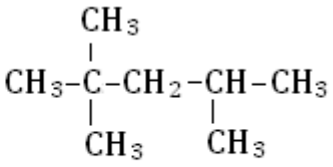
❖ Define Octane number? Explain in detailed.

- Anti knocking property of a fuel is expressed in terms of octane number.
- n – Heptane knocks very badly and an anti knocking property value zero is assigned to it where as iso octane has very high anti knocking property. So, its value is assigned as 100.



n - heptane

Anti knocking value = 0



Iso octane

Anti knocking value = 100

- **Octane number is defined as the percentage of iso octane in a mixture of iso octane and n- heptane which has same knocking characteristics as that of test fuel under same set of conditions.**
  Ex: Octane number of test petrol is supposing 77. It means that the knocking properties of the test petrol are similar to that of a fuel which contains 77% iso octane and 23% n – heptane.
- ♠ Higher the octane number, greater is the anti knocking property of fuel (good fuel).

Example	Octane number
Benzene	106
Iso pentane	90
Cyclo hexane	77
n – pentane	62
n – hexane	26

20) **Define Cetane number? Explain in detailed.**

- Quality of diesel is expressed in terms of Cetane number.
- If the diesel undergoes ignition as soon as it is injected, it is good fuel.
- It should have very short interval between injection and ignition.

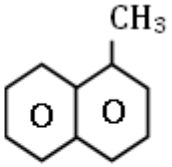
- The hydrocarbon Cetane (n – hexa decane) has a very short ignition delay and an arbitrary value of 100 has been assigned to it where as α – methyl naphthalene has very long ignition delay and hence 0 value is assigned to it.

$CH_3-(CH_2)_{14}-CH_3$

n - hexa decane

Cetane

Anti knocking value = 100



α - Methyl Naphthalene

Anti knocking value = 0

- **Cetane number of a diesel fuel may be defined as the percentage of Cetane in a mixture of Cetane and α – methyl naphthalene which has same ignition characteristics of test fuel under same set of conditions.**
- Cetane number of various hydro carbons is in the following order.
  Aromatics < Branched chain alkanes < Alkenes < Cyclo paraffins < n- alkanes
- The hydrocarbon with good Cetane number has poor octane number. A good fuel to diesel engine is a bad fuel to petrol engine.

Φ Differentiate Octane number and Cetane number.

	Octane number		Cetane number
1.	Octane referred for petrol	1.	This is referred for diesel
2.	Petrol with straight chain alkanes has lower octane number.	2.	Diesel with straight chain alkanes has higher cetane number.
3.	Low octane petrol in petrol engine produces loud cracking noise.	3.	Low cetane diseal in diesel/engine produces rattling metals noise and intese vibrations.
4.	Sudden combustion of hydrocarbons produces knocking in petrol engine.	4.	Delay in combustion causes knocking in diesel engine.
5.	Combustion decreasing chemicals are added in petrol to increase octane number.	5.	Combustion rate increasing chemicals added in diesel to increase cetane number.
6.	Octane number is considered to lower mol. wt. alkanes	6.	This is considered for mainly higher mol.wt. alkanes.

Gaseous fuels:

Gaseous fuels occur in nature, besides being manufactured from solid and liquid fuels.

❖ **What are the advantages and disadvantages of gaseous fuels ?**

Gaseous fuels due to ease and flexibility of their applications, possess the following advantages over solid or liquid fuels :

1) They can be conveyed easily through pipelines to the actual place of need, thereby eliminating manual labour in transportation.
2) They can be lighted at ease.
3) They have high heat contents and hence help us in having higher temperatures.
4) They can be pre-heated by the heat of hot waste gases, thereby affecting economy in heat.
5) Their combustion can readily by controlled for change in demand like oxidizing or reducing atmosphere, length flame, temperature, etc.
6) They are clean in use.
7) They do not require any special burner.

8) They burn without any shoot, or smoke and ashes.
9) They are free from impurities found in solid and liquid fuels.

Disadvantages:

1) Very large storage tanks are needed.
2) They are highly inflammable, so chances of fire hazards in their use is high.

Φ Write a short note on Natural gas.

- ✓ Natural gas is obtained from wells dug in the oil bearing regions .
- ✓ When natural gas occurs along with petroleum in oil wells it is called '*wet gas'*.
- ✓ The wet gas is treated to remove propane, propene , butane and butene which are used as LPG.
- ✓ On the other hand when the gas is associated with crude oil, it is called as '*dry gas'*.
- ✓ The natural gas is purified to remove objectionable ingredients such as water, dust, H_2S, CO_2, N_2 and heavier liquefiable hydrocarbons.
- ✓ The approximate composition of natural gas is CH_4 = 70-90%; C_6H_6 = 5-10%; H_2 = 3%; and the remainder = $CO+CO_2$
- ✓ Calorific value =12000-14000 Kcal/m^3

Uses:

- ✓ It is an excellent domestic fuel and can be conveyed over very large distances in pipe lines .
- ✓ A large number of chemicals are synthesized from natural gas
- ✓ It is also used as raw material for the manufacture of carbon black and hydrogen
- ✓ Synthetic proteins is obtained by micro biological fermentation of methane

❖ **Write a short note on CNG (Compressed natural gas).**

- CNG is natural gas compressed to a high pressure of about 1000 atmospheres.
- It is an odour less , non toxic gaseous mixture .
- CNG is measured in units of Gasolin Gallon Equivalent (GGE).
- The composition of CNG is CH_4 (90%), Other constituents are ethane ,propane , gases like N_2, CO etc..

Propreties:

- Light wight ,gaseous fuel. It mixes with air easily .
- It has a high auto-ignition temperature (540^0C) and narrow range of flammability.
- CNG does not contaminate with lubricating oils, thus increases the life of the IC engine .
- It requires more space for storage .
- The calorific value of CNG is 900KJ/mole

Uses:

1. Majorly used as fuel in automobiles like cars,autos,trucks,buses etc..
2. It is also used as fuel for locomotive diesel generators to generate electricity, that drive the motors of trains.

❖ **Write a short note on LPG (Liquified petroleum gas).**

- It is also called as Bottled Gas (or) Refinery Gas.
- LPG is obtained as a by-product during the cracking of heavy oils or from natural gas.
- The main constituents of LPG are n-butane, iso-butane, butylene and propane
- LPG is supplied under pressure in containers under the trade name like Indane, Bharat gas, H.P etc..
- LPG is dehydrated and desulphurised.
- Its Calorific value is about 27800 Kcal/m^3.
- LPG consists of hydrocarbons of such volatility that they can exist as gas under atmospheric pressure but can be readily liquefied under pressure.

Uses:

1. The largest use is as domestic fuel.
2. This is also used widely as an industrial fuel
3. LPG is used as a fuel in certain class of vehicles like trucks and tractors.
4. LPG leaded with tetramethyl lead can be used as the railway diesel locomotives

Disadvantage: Handling has to be done extremely carefully to avoid hazards.

❖ Write a note on Biodiesel?

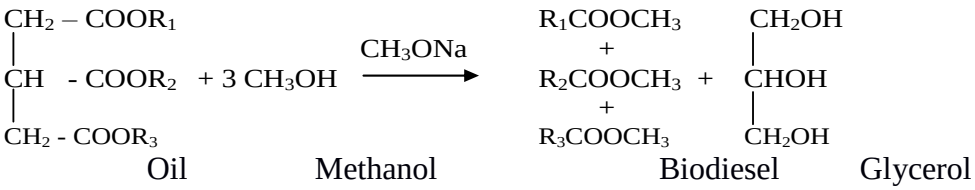
Definition :

Chemically biodiesel is the mixture of methyl esters of long chain carboxylic acids. Biodiesel is obtained by transesterification of vegetable oil or animal fats with methyl alcohol using catalyst sodium metal or sodium methoxide. (Transesterification is the process of converting one ester to another ester).

Reaction for Biodiesel Formation :

During the chemical conversion of vegetable oil to biodiesel we get water soluble glycerol and a small amount of sodium soaps. The water soluble part can be easily separated from biodiesel by washing the mixture with water. The alkaline sodium methoxide catalyst, saponifies some small amount of oil to give soap.

Vegetable Oil + Methanol + Catalyst ⇌ Biodiesel + Glycerol



Compounds present in biodiesel are like,

methyl palmitate	$H_3C - (CH_2)_{14} - COOCH_3$
methyl stearate	$H_3C - (CH_2)_{16} - COOCH_3$
methyl oleate	$H_3C - (CH_2)_7 - CH = CH - (CH_2)_7 - COOCH_3$
methyl linoleate	$H_3C - (CH_2)_5 - (CH = CH)_2 - (CH_2)_7 - COOCH_3$

Advantages of Biodiesel :

1) Biodiesel is cheaper, as it is manufactured from cheap, nonedible or waste oil or animal fats.
2) It has high cetane numbers 46 to 54 and high C.V. of about 40 kJ/gm.
3) It is regenerative and environment friendly.
4) It does not give out particulate and CO pollutants, as 0 atoms in biodiesel help for complete combustion.
5) It has certain extent of lubricity, due to higher oiliness of the esters.
6) Its use provides good market to vegetable oils and reduces our dependence on diesel on foreign countries, saving currency.
7) It is clean to use biodiesel in diesel engines.