Unit-2 Fuel

Fuel:- Any material which produces a large amount of heat energy on complete combustion, the heat Energy can be utilized for domestic & industrial purpose.

unit ⇒ Calorie or Kcal

Calorific value:- The total amount of heat produced by unit mass or volume of fuel on complete combustion is known as calorific value.

Gross calorific value:- The amount of heat produced by combustion of fuel & gases & volatile matter is allowed to coal is known as gross calorific value. (HCV)
(HCV ⇒ High calorific value)

Net / low Calorific value:- The amount of heat produced after combustion, when volatile matter / gases are allowed to escape in the atmosphere.

$$HCV = LCV + \text{Heat of vaporization}$$

Note Combustion ⇒ burning in presence of O_2.

Types of Fuel :- based on physical state-

(1.) Solid fuel ⇒ Coal, wood, charcoal etc.

(2) liquid fuel ⇒ Petroleum.

(3) Gaseous fuel ⇒ LPG, CNG, Coal gas, biogas.

Flash Point lower temp. at which an oil on vaporisation gives sufficient quantity of vapours.
(To form an explosive mixture with air)

for gasoline ⇒ 45°C
lubricant → 220°C

Classification of Coal :- (fossil fuel)

on the basis of % of Carbon presence.

(1.) **Peat** :- First stage of coal formation.
→ low catagory of coal.
→ Soft & spongy. C → 57%
→ minimum calorific value (4125 – 5400 kCal/kg)
→ Used for domestic fuel.
→ Leaves behind ash & smoke after burn.

(2) **Lignite** :-
more compact & homogenous than peat.
→ C = 60 to 70 %.
→ Used in Household fuel, boiler fuel, manufacture of producer gas.

(4) **Anthracite** :- C = 90 to 95%.
→ best quality of coal. burns with blue flame.
→ contains least amount of volatile / moisture.

(iii) Bituminous Coal (Common Coal)

→ widely used as a fuel.
→ % C ≈ 75 to 90%.
→ burns with long smoky & bright flame.

* Pulverisation of Coal :-

Coal is converted into powder form is known as pulverisation.

→ It increase surface area of coal & burning becomes easier.

* Carbonasation of Coal :-

Coal is heated strongle in absence of air, it converts into coke.

Coke is better then coal.

$$\text{Coal} \xrightarrow[\text{absence of air}]{\text{heat}} \text{Coke}$$

All the volatile matter are removed by heating.

Ash of coke is lesser then coal.

* Water equivalent :- Amount of heat required to raise the temperature of water by 1°C known as water equivalent.

Analysis of Coal :- checking the quality of Coal.

(i) Ultimate Analysis (ii) Proximate Analysis

(b) Proximate Analysis :-

It consists of determination of combustion value ash, moisture, volatile matter.

(i) Moisture content -

powdered coal is taken in silica crucible to heated. and cooling. for 1 hr

$$\% \text{ of moisture} = \frac{\text{loss in weight}}{\text{weight of coal}} \times 100$$

(ii) Volatile content :-

moisture free coal heated in muffle furnace. for 7 to 8 minute.

$$\% \text{ volatile} = \frac{\text{loss in weight}}{\text{weight of coal}} \times 100$$

(iii) Ash :-

volatile free coal heated at 700 - 750° C. in presence of oxygen.

$$\% \text{ ash} = \frac{\text{weight of ash}}{\text{weight of coal}} \times 100$$

(iv) Fixed carbon

The remain material is known as fixed carbon.

$$\% \text{ fixed carbon} = 100 - (\% \text{ moisture} + \% \text{ volatile} + \% \text{ Ash.})$$

* Significance :-

~~provides quality of coal~~

→ provide information about quality of coal.

→ Fixed carbon ↑ → calorific value ↑ → quality ↑

→ moisture ↓ → volatile ↓ → quality ↑

→ less Ash → quality ↑

* Ultimate Analysis

determination of % of C, H, N, S and ash.

(1) % of Carbon

Coal is burnt in presence of oxygen, absorbed by KOH

$$C + O_2 \longrightarrow CO_2$$
$$12g \quad 32g \quad 44g$$

$1g\ CO_2 \longrightarrow \frac{12}{44}$ g of Carbon.

$$\% \text{ of Carbon} = \frac{\text{mass of } CO_2}{\text{mass of Coal sample}} \times \frac{12}{44} \times 100$$

mass of CO_2 ⇒ initial (KOH) − final (KOH)

(2) % of Hydrogen

H ↑ → Calorific ↑ → Quality of Coal. ↑

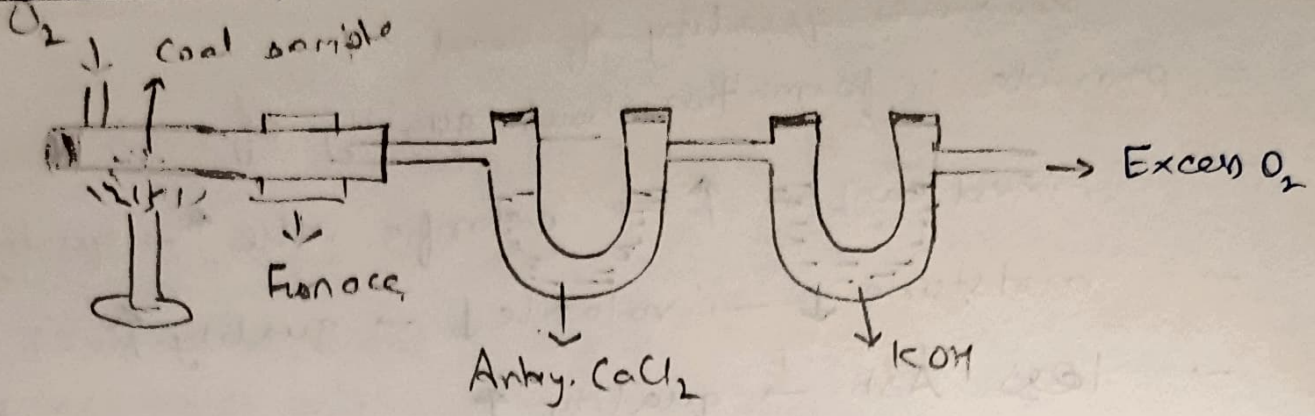
$$2H_2 + O_2 \longrightarrow 2H_2O$$
$$2g \quad 18gm$$

$1gm\ H_2O \longrightarrow \frac{2}{18}$ gm H_2

$$\% \text{ of } H = \frac{\text{mass of } H_2O}{\text{mass of sample coal}} \times 100 \times \frac{1}{9}$$

H is absorbed by the $CaCl_2$ (Anhydrous)

(iii) % of Sulpher



(iii) % of Sulpher

Sulpher ~~Coal~~ is converted into sulphate. with $BaCl_2$

$$\% \text{ of } S = \frac{\text{mass of } BaSO_4}{\text{mass of Coal sample}} \times \frac{32}{233} \times 100$$

$$S + O_2 \longrightarrow SO_2$$

$$SO_2 \rightarrow Na_2SO_4 \xrightarrow{BaCl_2} BaSO_4 \downarrow$$

(PPt)

(iv) % of Nitrogen

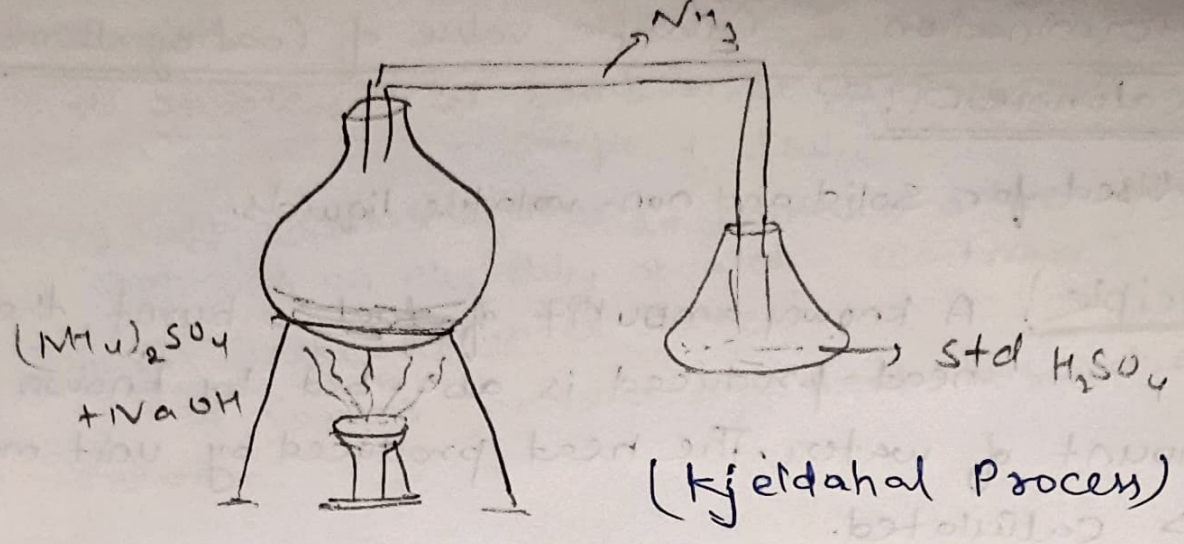
N is converted into amonium sulphet. $(NH_4)_2SO_4$

$$(NH_4)_2SO_4 + NaOH \xrightarrow{\Delta} NH_3 \uparrow$$

$$NH_3 + H^+ \longrightarrow NH_4^+$$

$$\% \text{ of } N = \frac{\text{Volume of Std. Acid}}{\text{Mass of Coal sample}} \times \text{Normality} \times 1.4$$

Strength = Normality × eq. weight.



(Kjeldahal Process)
for N

Significance -

→ % C & % H decides the calorific value.

→ % C ↑ or % H ↑ ⇒ C.V. ↑

→ % S is undiserable So it should be remove.

→ % N is also not diserable.

→ % O supports the combustion & % O ↑ then ~~oxygen~~ C.V. ↓

* ~~Combination of Coal by otto-halfmann's by product oven method~~ -

* Determination of Calorific value of Coal by Bomb calorimeter :-

Used for solid and non-volatile liquids.

Principle A known amount of fuel is burnt, the heat produced is absorbed by known amount of water. The heat produced by unit mass/v. is calculated.

heat liberated = $m \times C = \Delta t (W + w)$ = heat absorbed.

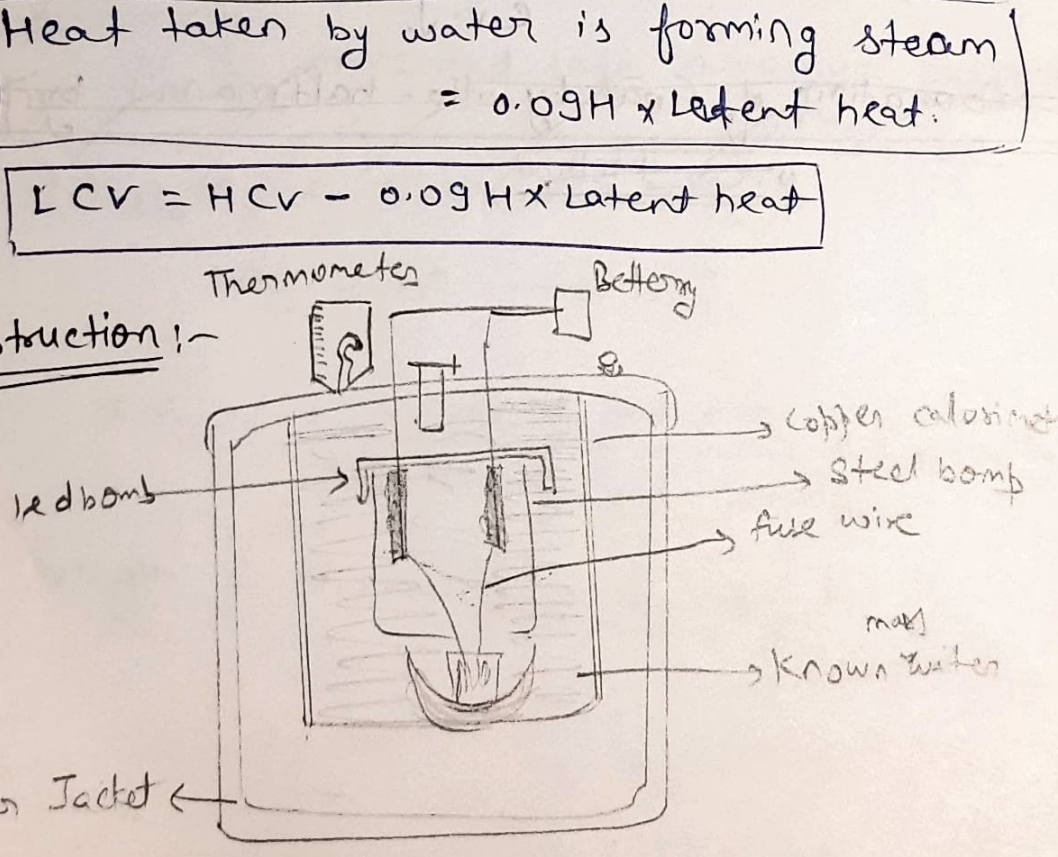
$$C = \frac{\Delta t (W + w)}{m}$$

here Δt = temp. diff.
m = weight of fuel ignited.
W = amount of water
w = ~~am~~. water eq. of calorimeter.

* Heat taken by water is forming steam
= 0.09H x Latent heat.

* LCV = HCV − 0.09H x Latent heat

Construction :-



It consists

(i) Stainless steel bomb ⇒ It contains given sample of feul.

(ii) Copper Calorimeter ⇒ It contains a thermometer which is an electrically operated. (Beckmann)

(iii) Air Jacket & Water Jacket.
(& Cover) prevent any heat losses due to radiation.

Working

→ A known mass of given fuel taken in crucible.
→ Crucible is supported over the ring.
→ lid is tightly screwed, bomb is filled with O_2 at 25 atm. Fuse wire is stretched across the electrodes.
→ It is lowered down in copper calorimeter (water) It is connected to 6V battery & circuit is done. Now sample starts burning & heat is liberated. & temp is measured.

Correction For more accurate result.

(i) Fuse wire correction ⇒ it converts electrical energy into heat energy.
So this should be substracted.

(ii) Acid correction ⇒ N, S, ⇒ oxidized at high pressure & temp. and release heat.
that must be substracted.

(iii) Cooling correction ⇒ Δt ⇒
when temp of water becomes higher then surrounding. then water vapor cool down at room temp. There is loss of head. (Added)

So After correction -

$$(HCV) = \frac{(W+w)[\Delta t + \text{cooling correction} - (\text{Acid} + \text{fuse})]}{\text{mass of fuel.}}$$

* Manufacturing of Coke

Caking Coal :- Coal on heating initially loose moisture & volatile matter & at higher temp the mass becomes soft., plastic, fuses to give a cohered mass.

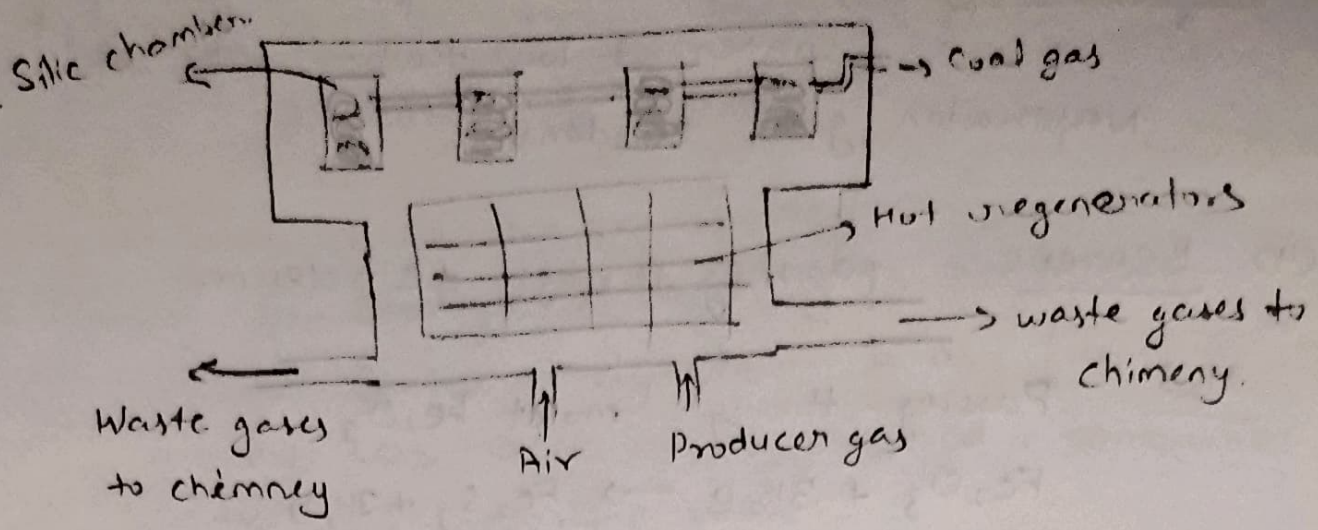
Non-Cacking coal :- Coal which form a weak coherent mass on heating.

Coking Coal :- If produced coke is hard, porous, strong then coal from.

* Otto Hoffmann Oven method or by product coke oven method -

Principle This method operates on regenerative principle of heat economy. i.e. utilization of the waste gases or fuel gases for heating of the checker works of brick.

Construction :- oven consists of a number of narrow silica chambers which are vertically erected side by side with vertical flues or interspace for combustion.



Working → Coal is fed in silica chamber. It is heated for 20hr at 1200°C high temp. When the carbonation is completed, heat is taken out from the chamber. and coke is quenched with water.

Quenching :- By cooling of red hot coke in inert gases. It is quenched with water and prevent oxidation.

Recovery of by products :- It contains tar, ammonia, H_2S, napthalene & moisture

(1) Tar :- Coke passed through NH_3 (Ammonia) gas and it saperate tar.

(2) Ammonia :- by sprading water.

$$NH_3 + H_2O \longrightarrow NH_4OH$$

$$\downarrow H_2SO_4$$

$$(NH_4)_2SO_4 \Leftarrow \text{(fertilizer)}$$

(iii) Napthalene :- The gases are passed where water at low temp. is sprayed.

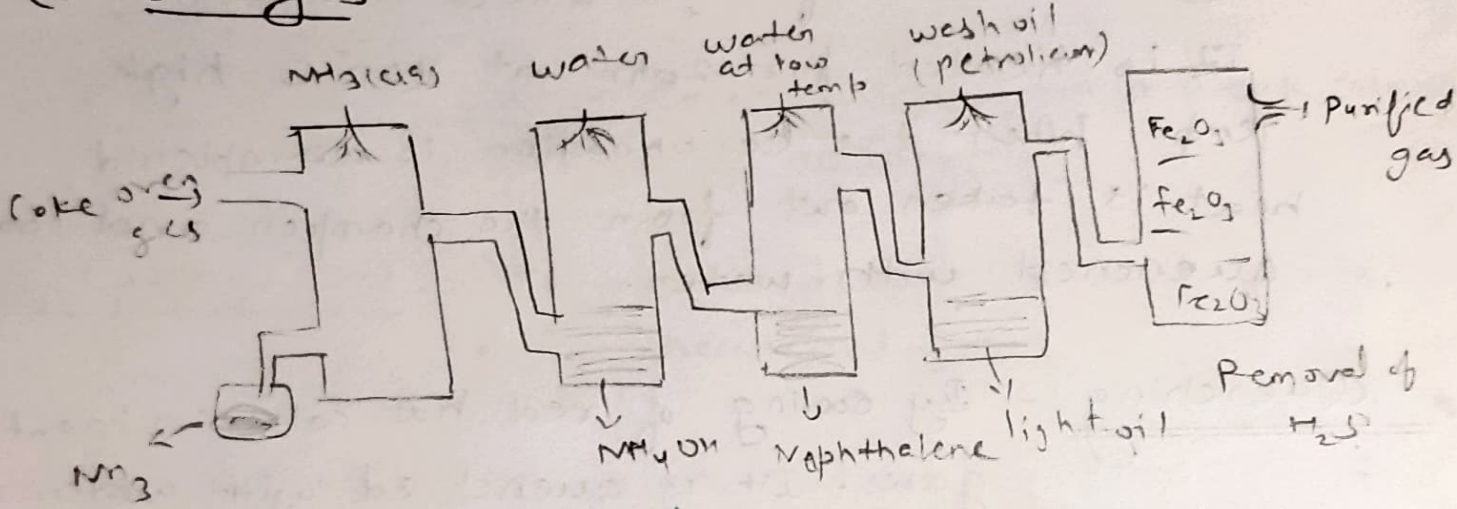
Napthalen gets condensed.

(iv) Benzene :- passing through petroleum.

H_2S Passing through moist Fe_2O_3

$$Fe_2O_3 + 3H_2O \longrightarrow Fe_2S_3 + 3H_2O$$

(v) Coal gas



Note Dulong's Formula for calculation of calorific value.

$$HCV = \frac{1}{100}\left[8080C + 34500\left[H - \frac{O}{8}\right] + 2450S\right]$$

& LCV = HCV − 0.09H × latent heat of vapourization

Q On analysis of fuel, give the following result.

% C = 82	% H = 8	% N = 1.4	latent heat = 587 kcal
% O = 3	% S = 2.5	% ash = 2.1	

Calculate gross & net calorific values

Sol^n $$HCV = \frac{1}{100}\left[8080 \times 82 + 34500\left[8 - \frac{3}{8}\right] + 2450 \times 2.5\right]$$

$$HCV = 9317 \text{ kCal/kg}$$

Now LCV = 9317 − 0.09 × 8 × 587

= 5894.36 kCal/kg

* **Liquid Fuels:-** mainly obtained by fractional distillation of petroleum.

Advantage (i) can be transported easily by pipes.
(ii) Storage & handling is much easy.
(iii) Comperatively cleaner & ash free.
(iv) Less excess air is required in combustion.
(v) High calorific value.

Refining of Petroleum:- Firsty Mining of petroleum in which green viscus liquid oil is found which is known as crude oil.

The steps are-

(1) **Demulsification:-** Separation of water from petroleum.

→ Petroleum = emulsion of oil + salt water.
[medium] [Disperse phase charged.]

It is passed through the electrodes (heavily charged) Droplets neutrilized and convert into drops.

(2) **Removel of Sulpher:-** crude petroleum is treated with Copper oxide.

* (a) $Na_2PbO_2 + 2RSH \longrightarrow Pb(SR)_2 + 2(NaOH)$
↓
Lead mercaptide

(b) $Pb(SR)_2 + S \longrightarrow PbS + RSSR$
Disulphide

disulphide → Sulpher → sweetning of petroleum

(3) Removal of olefins by treating gasoline with 80% H_2SO_4 (cold)
↳ form Alcohol & ester.

(4) Fractional Distillation :-

Principle :- The fraction having higher boiling point is condense at the bottom of the tower.

→ Crude oil heated at 400°C temp. & vapours passed through the tower.

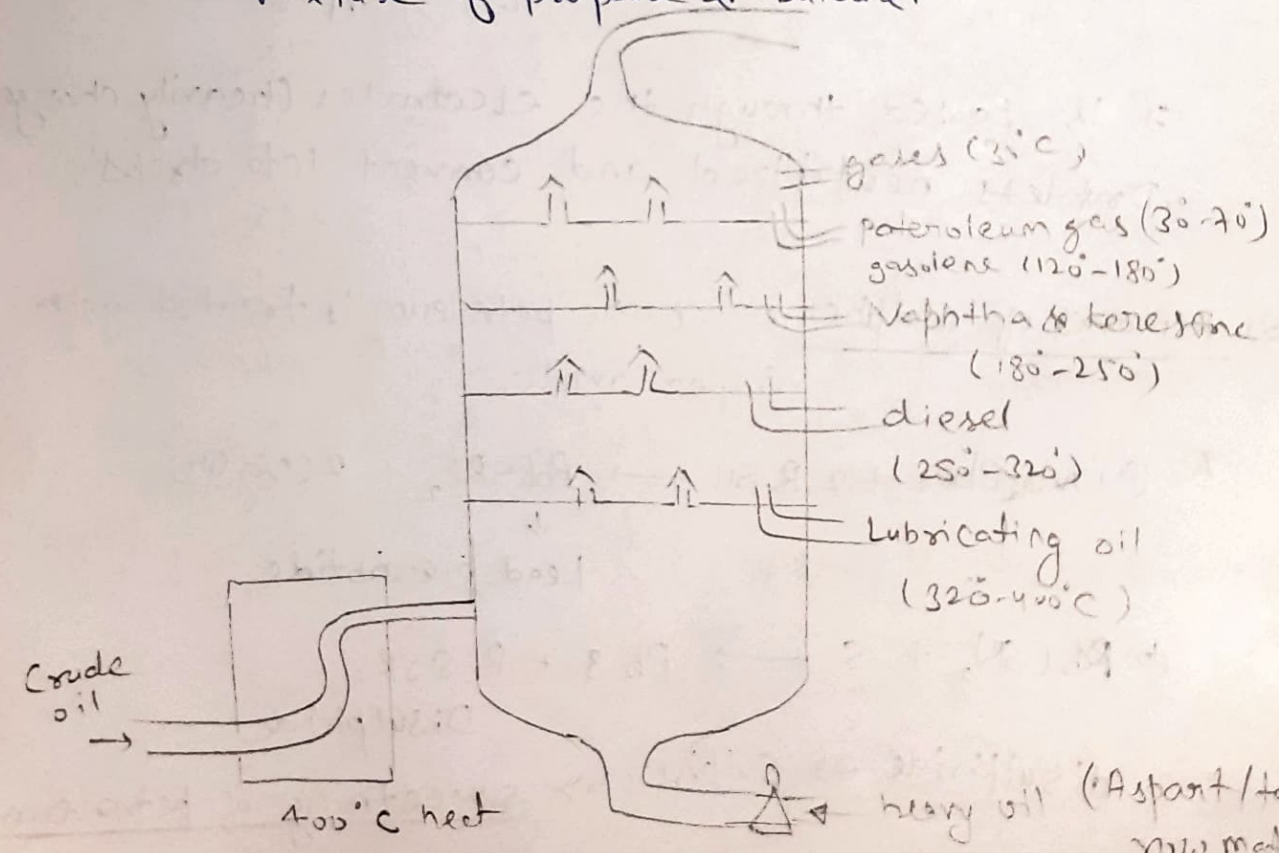
main Components.

(a) Gasoline :- used as fuel in internal combustion engines of aroplanes.

b) Kerosene :- Good fuel for Jet engines.

(c) Fuel oil :- $-C_{16}H_{34}-$ known as diesel oil.
used in diesel engines.

d) Liquified Petroleum gas used in domestic fuel.
mixture of propane & butane.



* **Cracking** higher H.C. molecule $\xrightarrow[\text{(cracking)}]{\text{Decomposition}}$ lighter H.C molecule.

Eg $C_{10}H_{22} \longrightarrow C_5H_{12} + C_5H_{10}$
Decane → Pentane + Pentene

Methods of cracking –

(i) Thermal cracking (ii) Catalystic cracking.

(1.) **Thermal cracking :–**

Heavy oil subjected to high Temp. & pressure.

(a) liquid phase

In this process heavy oil is used in liquid form for cracking

(b) vapour phase

In this process heavy oil is used in vapourised form for cracking.

→ The quality of petrol is better.

(2) **Catalystic cracking :–**

In presence of catalyst, cracking is done.

Catalyst → Alumina (Al_2O_3), aluminium silicate or zeolite.

→ better quality of petrol.

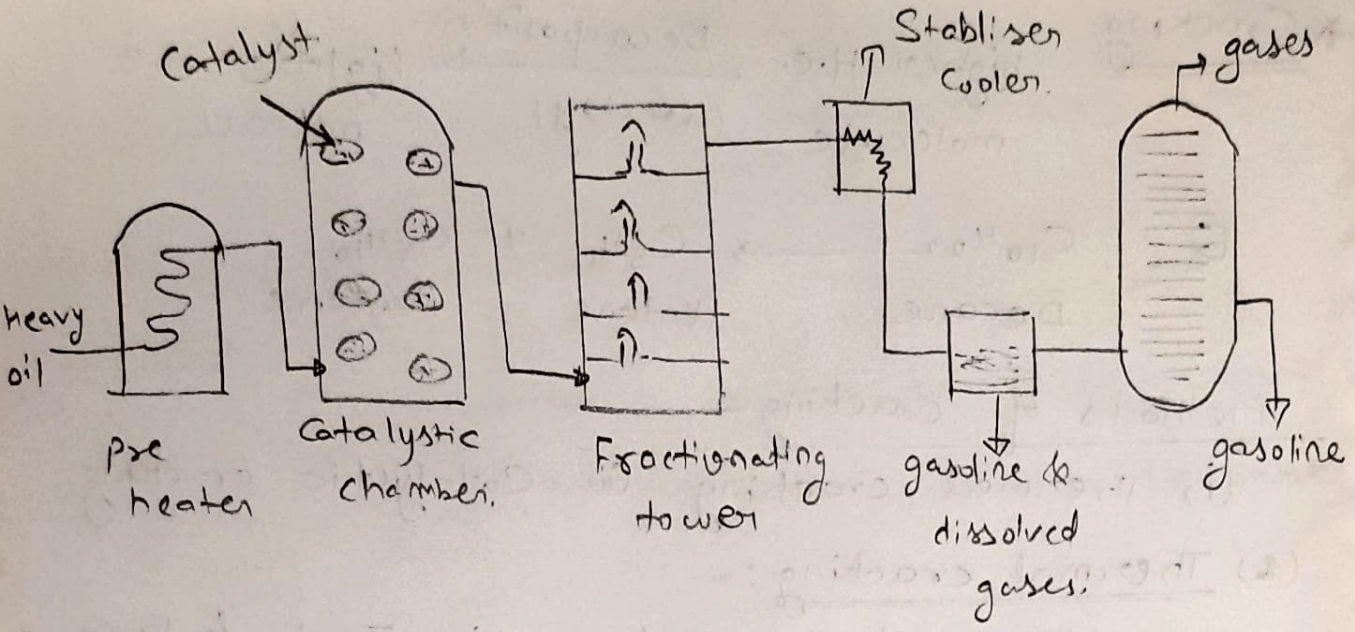
Two methods

(a) **Fixed bad catalystic :–**

Heavy oil vapours are preheated at 425°–450°C

Catalystic is used in ~~powder~~ solid form.

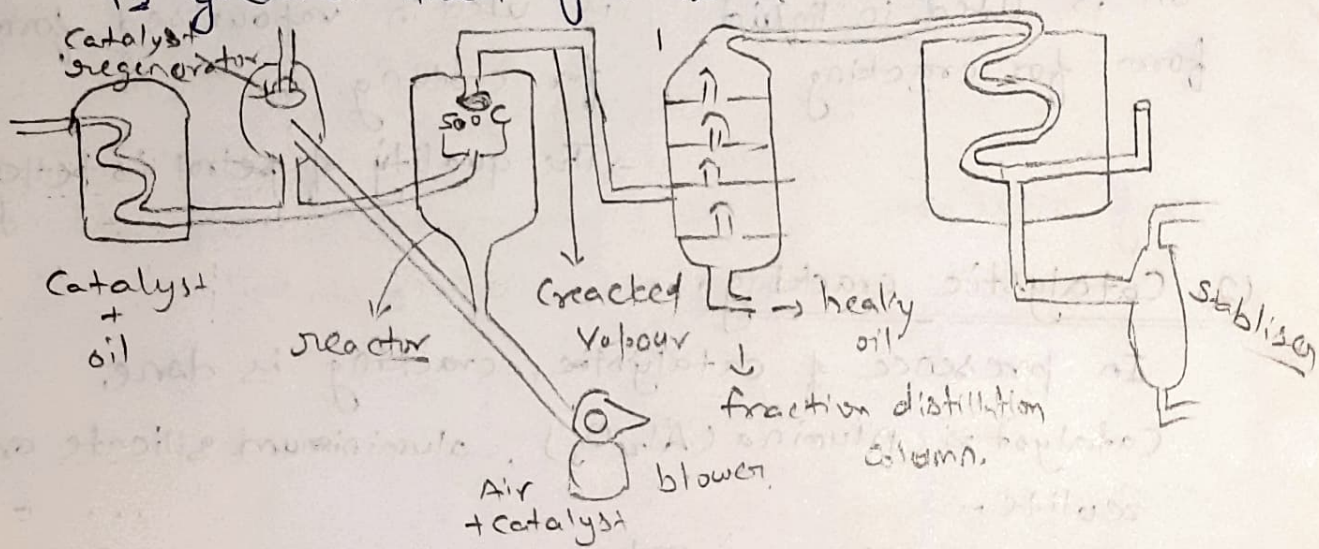
40% heavy oil → gasoline with 2–4% carbon.



(b) ~~Fixed~~ Moving bed catalystic:-

Catalysti is used in powder form. (behaves like fluid)

→ More efficient because surface area of powder is greater then of a solid state.



Advantage of ~~moving~~ ~~cryst~~ catalystic cracking

(i) higher yield

(ii) better equality

(iii) Better anti ~~knocking~~ properties.

★ **Synthetic Petrol :-** A petrol like mixture.

→ When coal & its product are hydrogenerated they convert into petroleum like substance at appropriate temp & pressure.

Production methods -

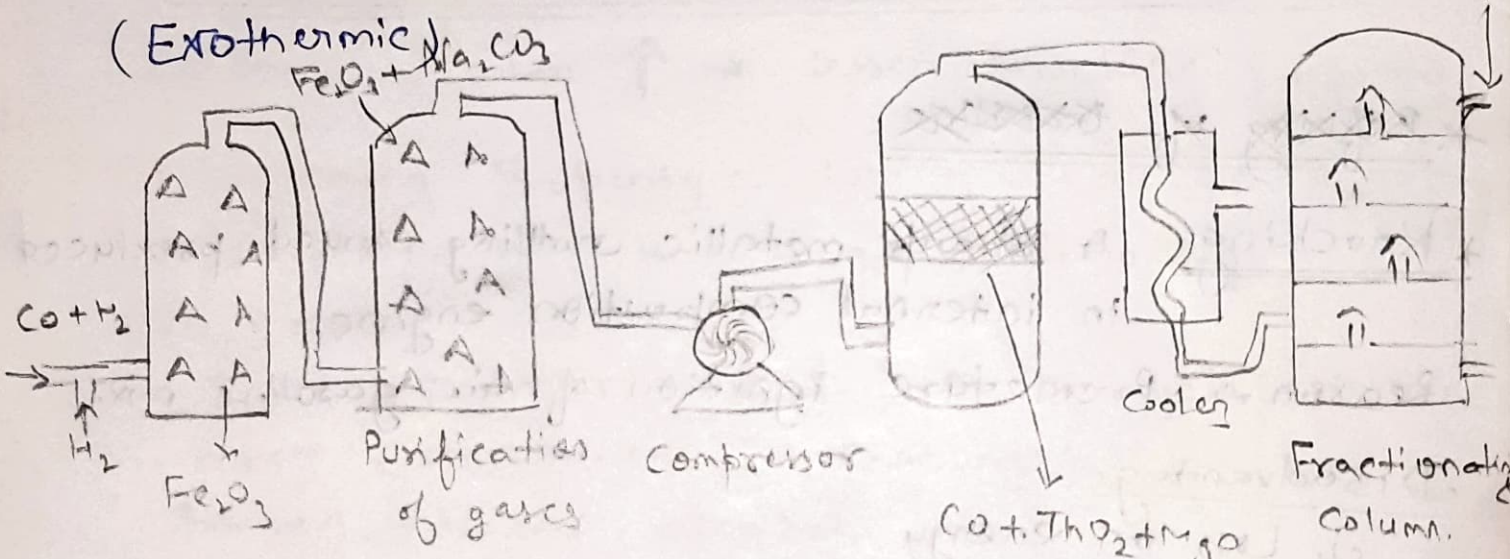
(a) Fischer - Tropsch Process :-

$CO + H_2$ (water gas) passed over catalyst (zinc, Cr_2O_3, MnO_2) at high temp & pressure.

$$n\,CO + 2n\,H_2 \longrightarrow C_nH_{2n} + n\,H_2O + \text{Heat}$$
(Alkene)

$$n\,CO + (2n+1)\,H_2 \longrightarrow C_nH_{2n+2} + n\,H_2O + \text{Heat}$$
(Alkane)

(Exothermic)



→ Expensive.

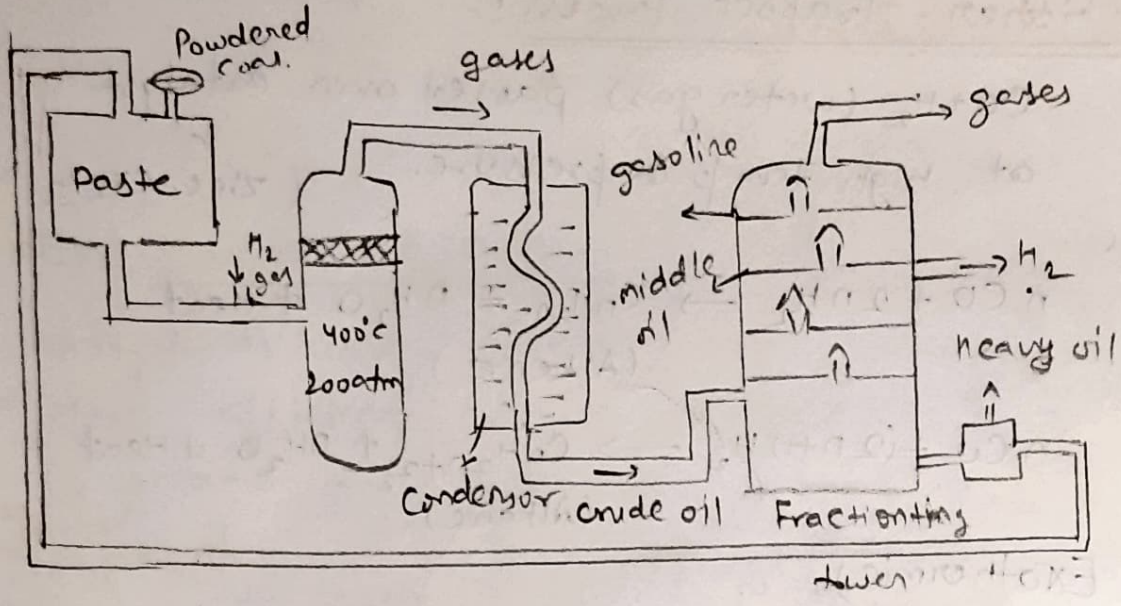
→ Usful in emergency.

(b) Bergius Process

Paste of coal powder + heavy oil + H_2 gas is used.

at 400 to 480°C & 200-250 atm.

→ 60% of coal is converted into liquied fuel.



* ~~Refining of Gasoline~~

* **Knocking** A sharp metallic rattling sound produced in internal combustion engine.

Reason ⇒ Premeture ignition of air gasoline mix.

Disadvantage

(i) Loss on energy

(ii) Damage of engine & piston.

(iii) ~~De~~ Decrease of efficiency.

Strength of knocking

Straight chain alkanes > Branched chain alkane > alkene > cycloparaffin > Aromatics.

Note -> knocking property decrease with compactness of molecules, double bonds & cyclic structure.

Octane Number (Rate of knocking)

Octane Number of Isooctane = 100 (Anti knocking property is 100 percent)

(2,2,4.- tri methyl pentane)

for n-heptane = 0 (0% Anti knocking.)

Definition => The proportion of iso-octane in a mixture is known as octane Number.

(octane Number ↑ → lesser knocking property)

Antiknocking Property :- which reduces knocking property are known as Antiknocking substance.

Eg TEL (Tetra ethyl lead), methy cyclo pentadiene MMT (Managnese Tri carbonyl) benzen, toluene, alcohol,

Note Lead is poisonous & causes of pollution. So TEL is banned.

Cetane Number % of cetane in the cetane & α methyl naphthalene mixture

n-hexa decane => 100 % (Quality of diesel fuel.)

2-methyl naphthalene => 0 %

Cetane Number ↑ → Good quality (Diesel)

Strength

n-alkane > naphthalene > Cyclo alkanes > Branched chain Alkane > Aromatics.

* Gaseous Fuel :-

Primary → Natural Gas (CNG)

Secondary → LPG, Coal gas, oil gas, coke oven gas.

Advantage

(i) High calorific value

(ii) Easy handling & transportation

(iii) Easy to use

(iv) Pollution less & eco-friendly.