Fuels

Fuels are substances which on combustion in the presence of air give out heat energy, usable for domestic or industrial purposes. The byproducts of this are CO_2 and water.

$$C_nH_{2n}+2 \Rightarrow CO_2 + \text{Water} + \text{heat}$$

Classification of fuels

1. **Primary fuels**
   - Also called natural fuels
   - Wood, petroleum, natural gas
2. **Secondary fuels**
   - Also called artificial fuels.
   - Derived from primary fuels.
   - Charcoal, petrol, coal gas

A good fuel has:

a. **Moderate ignition temperature:** Should ignite at a moderate temperature.
b. **Low moisture content**: Allows for less smoke/faster process/calorific value high
c. Low noncombustible matter: Non-combustible matter on the fuel causes clinkering of ash (hinder the supply of air and hence un-burn the fuel). Coal has ash in it even before burning as a component.
d. **Low cost and easily available**: obviously
e. Easy transportation and low storage cost: obviously
f. **By-products should not be harmful:** obviously
g. As little smoke as possible: obviously
h. Combustion should be easily controllable: Uncontrolled burning is fatal or inefficient.
i. **High calorific value**: Heat content of the fuel should be high.
   Calorific value of a fuel is **the total quantity of heat liberated when one unit of fuel is burnt completely.**

Calorific Value

1. **Gross Calorific Value / Higher Calorific Value**

$$HCV = (8080C + 34500(H-O/8) + 2240S)/100 \text{ kcal/kg}$$

Where C, H, O, S are the percentage of respective elements in the fuel. 8080, etc. are the calorific values of those elements.

2. **Lower Calorific Value**

$$LCV = HCV - \text{Latent heat of water vapour formed.}$$
$$LCV = HCV - 0.09H*587 \text{ kcal/kg}$$

**1 Kcal/kg = 1.8 B.Th.U / lb (british thermal unit per pound)

$$1\ kcal/m^3 = 0.1077\ B.Th.U/ft^3$$

A calorie is the heat required to raise the temperature of **1 kg of water** through one degree C.

A B.Th.U is defined as the heat required to raise the temperature of **one pound of water from 60 fahrenheit to 61 fahrenheit.**

Centigrade heat unit is the heat required to raise the temperature of **one pound water through 1 degree centigrade.**

$$1\ kcal = 2.2CHU = 3.968BTU$$

Solid fuel	Liquid fuel	Gaseous fuel
1. Calorific value: Their calorific value is low.	Their calorific value is high	Their calorific value is highest.
2. **Pollution:** Their ash content is high and they produces lot of smoke on burning.	Their ash content is low and they burn without smoke.	They are almost pollution free; they burn without smoke and ash less.
3. **Ignition temp and fire hazard:** Their possess moderate ignition temperature	Their ignition temp is low so there is a chance of fire hazard.	They have a very low ignition temp so they are highly inflammable and chances of fire hazard is highest.
4. **Cost:** Their production cost is low.	Cost is relatively higher than solid fuel.	They are more costly compare to solid and liquid fuel.

Solid fuel	Liquid fuel	Gaseous fuel
5. Transportation: They are easy to transport through normal carriage so cost is low.	They can be transported through pipelines hence it is more costly.	They can be conveyed through pipelines hence costly.
6. **Storage** Their storage needs lot of space but there is no risk.	Costly special storage tank is required for storing and safety precaution has to be taken to prevent fire hazard as most of them are highly inflammable and volatile	They can be compressed in cylinder so storage doesnot need lot of space. Safety precaution has to be taken to prevent fire hazard as they are highly inflammable and volatile.
3. **Mode of operation during combustion:** Their thermal efficiency is low and ignition temperature is high so large proportion of heat is wasted during combustion. They require a large excess of air for complete combustion. But the combustion operation cannot be controlled easily.	Their ignition temp is low so firing is easier and fire can be extinguished by stopping liquid fuel supply. The flame produced by burning can be easily controlled by adjusting fuel supply.	Their ignition temp is lowest so firing is very easy. The flame produced by burning can be easily controlled by adjusting fuel supply.

Classification of Coal

Wood, peat, lignite, bituminous, anthracite are the various types of coal in terms of quality.

	Wood	peat	lignite	bituminous	anthracite
Moisture	25	25	20	4	1.5
Carbon	50	57	60-80	83	93.3
Hydrogene	6	5.7	5	5	3
Calorific	4k	4.5k-5k	6.5-7	8.1-8.6	8700

Analysis of coal is done to:

1. **Decide the price of coal**
2. **Determine the quality**
3. **Specify use of coal for purposes**
4. Calculate the theoretical calorific value of the coal
5. **Calculate air requirement for complete combustion** and design furnace for box suitability. If it's more volatile(wood), the flame will be sooty. Accordingly, the furnace is designed and so on.

Types of Analysis:

1. Proximate Analysis: Does not carry any chemical test. Determines moisture, volatile matter content, ash, and fixed carbon content.
   Significance: 5M 10 points (main 4 points mein 10)
   a. **Moisture ✔**
      - Increases transportation cost
      - Helps in binding fines
      - Decreases heat content per kg
      - Increases heat loss due to evaporation

   b. **Volatile**
      - Increase in percentage of volatile matter, increases flame length
      - Sets minimum limit of furnace height and volume
      - Influences secondary oil support

   c. **Ash ✔**
      - Impurity that doesnt burn
      - Causes slagging problems in boiler
      - Increases transportation and storage costs

   d. **Fix Carbon: ✔**
      - Acts as main heat generator
      - Gives rough estimate of heating value of coal

   Procedure:

PROXIMATE ANALYSIS OF COAL :

Procedure:

Determination of Inherent Moisture: Transfer about 1g ($\mathbf{W_{coal}}$) of powdered air-dried coal sample into a previously weighed silica crucible. Place the open crucible with sample in an ***electric oven*** and heat it at about ***105 –110°C*** for an **hour**. Take out the crucible after one hour from the oven and cool it in a **desiccator** (containing moisture absorbing anhydrous calcium chloride). Then weigh the crucible with sample. Calculate the loss in weight.

Weight before heating – Weight after heating = Loss in weight of coal

Loss in weight = Weight before heating - Weight after heating

$$\% \text{ Moisture} = \frac{Loss\ in\ Weight}{Weight\ of\ Coal} \times 100$$

$$\% \text{ Volatile matter} = \frac{Loss\ in\ Weight}{Weight\ of\ Coal} \times 100$$

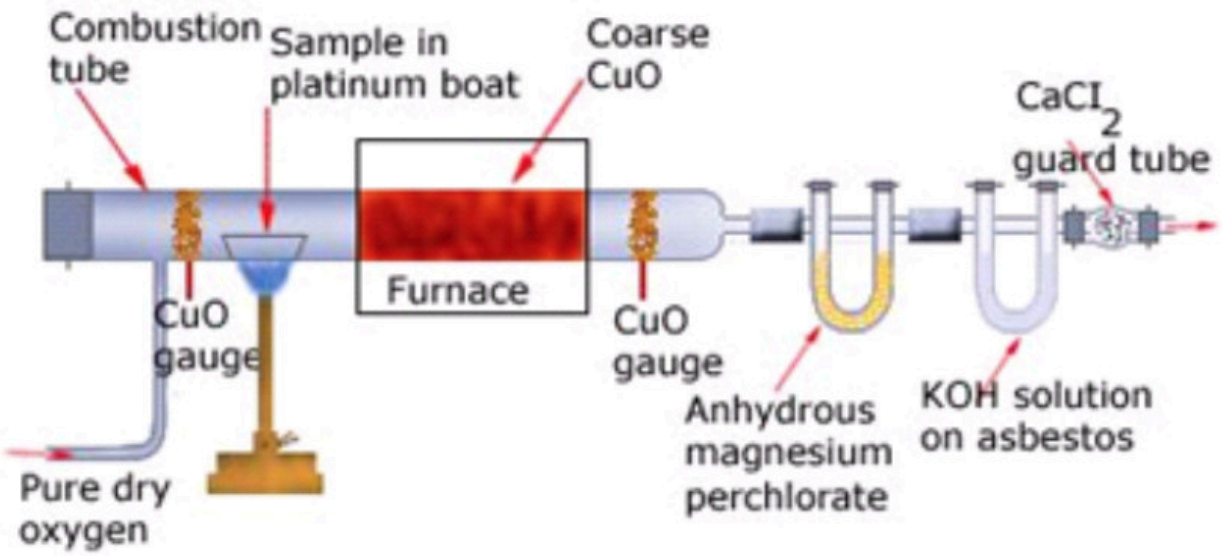
$$\% \text{ Ash} = \frac{Weight\ of\ ash\ left}{Weight\ of\ coal} \times 100$$

%Fixed Carbon content = 100 - %M + %VM +%Ash

2. Ultimate Analysis: Process of determining the composition of components of coal (% of C, H, S, N, O, and ash). This method is essential for utilization of coal for industries.
   Significance of UA:
   a. **Greater percentage of carbon and hydrogen means quality** and **efficiency** is higher. Hydrogen is also associated with moisture, so it affects the use to which the coal is put to use.
   b. **Sulfur releases as smoke** and causes acid. Although it contributes to calorific value, it's better to limit it.
   c. **Less nitrogen** is desirable. Nitrogen does not contribute, so it's better to not include it.
   d. **Oxygen is always lost as moisture in coal**, which is undesirable. So we prefer to not have any oxygen in our coal. High oxygen translates to high moisture, low calorific value, and low cooking power.

   Procedure:

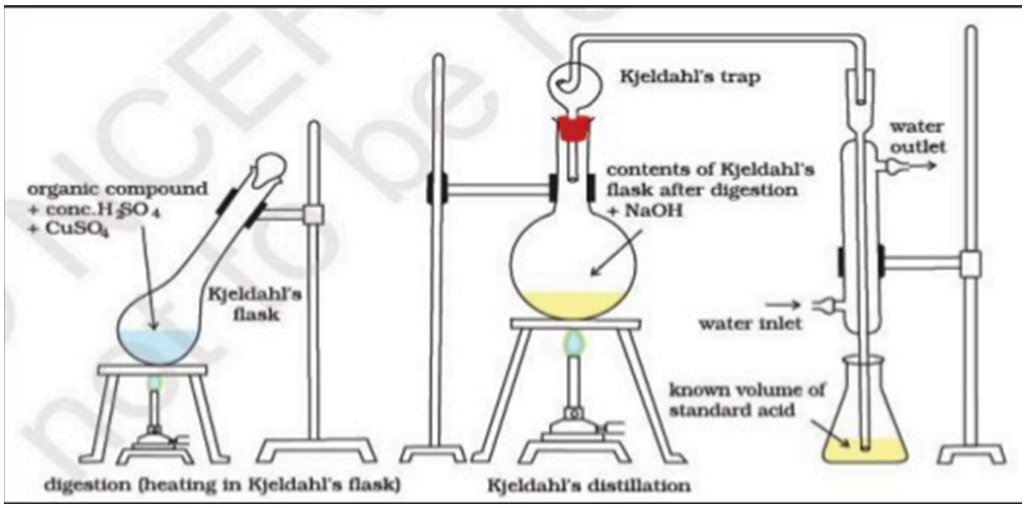
1. Carbon and Hydrogen method (Combustion method):
   An accurately weighed (1-2g) coal sample is burnt in a current of oxygen in the combustion chamber. As a result, C and H are converted into CO_2 and H_2O by combustion in the presence of oxygen. CuO gauges are present which trap the sulfur gases formed and convert to CuS that stays as powder. Co_2 and h2o are absorbed in KOH and $CaCl_2$ (taken in U-tubes) respectively, of known weights. The increase in weight of KOH and $CaCl_2$ after absorption gives the amount of CO_2 and H_2O formed.



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

$$\%H = \frac{Increase\ in\ weight\ of\ CaCl2\ tube}{weight\ of\ coal\ sample} \times 2 \times \frac{100}{18}$$

2. Determination of nitrogen (Kjeldahl's method)



1g of weighed powdered coal is heated with **conc h2so4** and **treated with excess KOH**.

Coal + conc h2so4 + excess koh

Liberated **ammonia** is distilled over and absorbed in a known volume of standard soln of acid. Unused acid is determined by back titration of standard NaOH.

$$\%N = \frac{volume\ of\ acid\ used * normality}{weight\ of\ coal\ sample} \times 1.4$$

$$\%S = \frac{weight\ of\ BaSO4\ ppt}{weight\ of\ coal\ sample} \times 100 \times \frac{32}{233}$$

%O = 100 - %(C+H+S+N+ash)

Power Alcohol and Synthetic Petrol

Definition: Pure and dry ethanol. Ethyl alcohol is used as an additive to motor fuels like petrol. When added, the efficiency/octane number of petrol increases. This petrol, with 5-10% concentration of ethanol, is called power alcohol.

Manufacture of Ethanol

1. By fermentation:

$$C_6H_{12}O_6 \rightarrow (\text{using yeast})\ 2C_2H_5OH + 2CO_2$$

2. Using molasses

$$C_{12}H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6(\text{glucose}) + C_6H_{12}O_6(\text{fructose})$$
$$C_6H_{12}O_6 \rightarrow (\text{using zymase})\ 2C_2H_5OH + 2CO_2$$

Benefits of power alcohol:

1. Ethyl alcohol is a good **anti knocking** agent (smoother combustion)
2. Power alcohol has an **octane number** of 90, while that of petrol is 65.
3. Any **moisture content present is absorbed** by alcohol.
4. Ethyl alcohol **contains oxygen** atoms, which help for **complete combustion** of power alcohol.
5. **Polluting emissions** of CO, hydrocarbons, and particulates are largely **reduced**.
6. Power alcohol is **cheaper** than petrol.

Disadvantages:

1. **Low calorific value:** Ethyl alcohol has calorific value 7000 cal/g much lower than that of petrol which has 11500 cal/g. However, this problem could be overcome by using a specially designed engine with higher compression ratio.
2. **Low power**: The output of the power generated is reduced up to 35%.
3. It has **high surface tension** and its atomization is difficult, especially at lower temperature, thereby causing starting trouble.
4. **Corrosion:** It **may undergo oxidation** reaction to form acetic acid, which corrodes engine parts.
5. As it contains oxygen atoms, the amount of air require for complete combustion is less, therefore, the carburetor and engine need to be modified. //useless

Biodiesel

What? A non-petroleum-based diesel fuel.
Composition: short chain alkyl (methyl or ethyl) esters
Made: Transesterification of vegetable oil or animal fat
Usage:(alone, or blended with conventional petro-diesel) in unmodified diesel-engine vehicles.
"Biodiesel" is standardized as mono-alkyl ester.

Benefits:

1. Reduction of greenhouse gases
2. Useful in electricity generation, reduces pressure on fossil fuels
3. environmentally friendly
4. Helps lubricate engine itself, reduce wear and tare
5. Similar power as diesel fuel

6. Home made
7. Safer

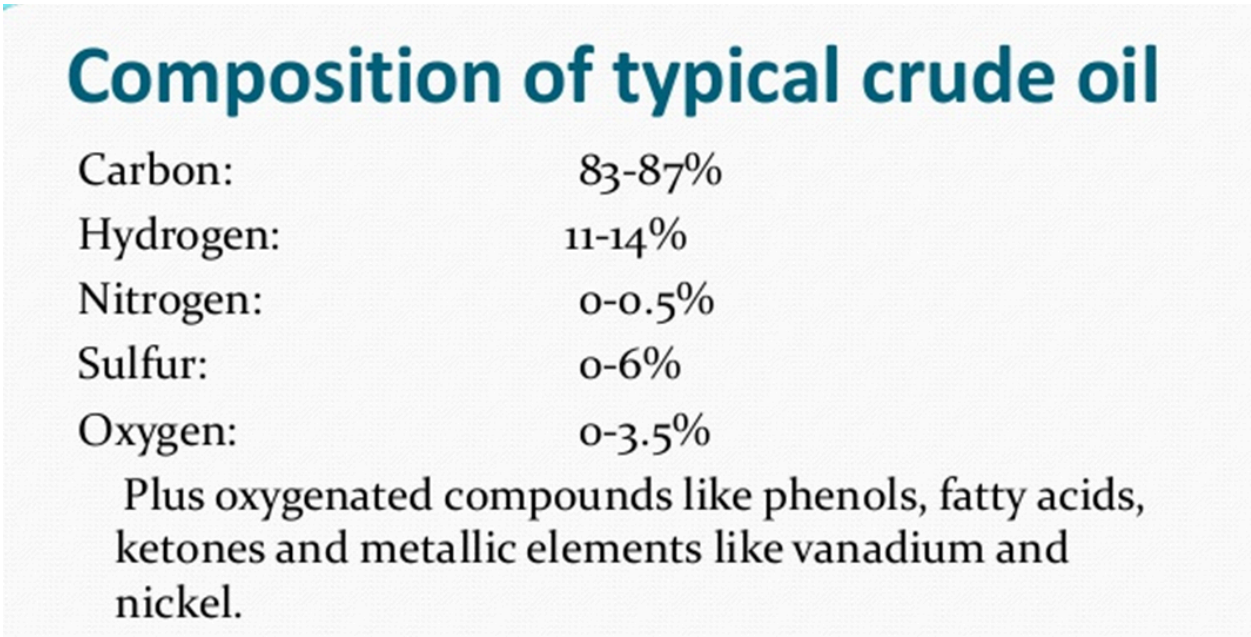
Disadvantages:

1. Storage not feasible
2. Gel in cold weather
3. High water content
4. High NOX emission
5. Decreases horsepower

Solution: mix 20% biodiesel with diesel.

Indian mission:

1. Using biodiesel in trains like shatabdi

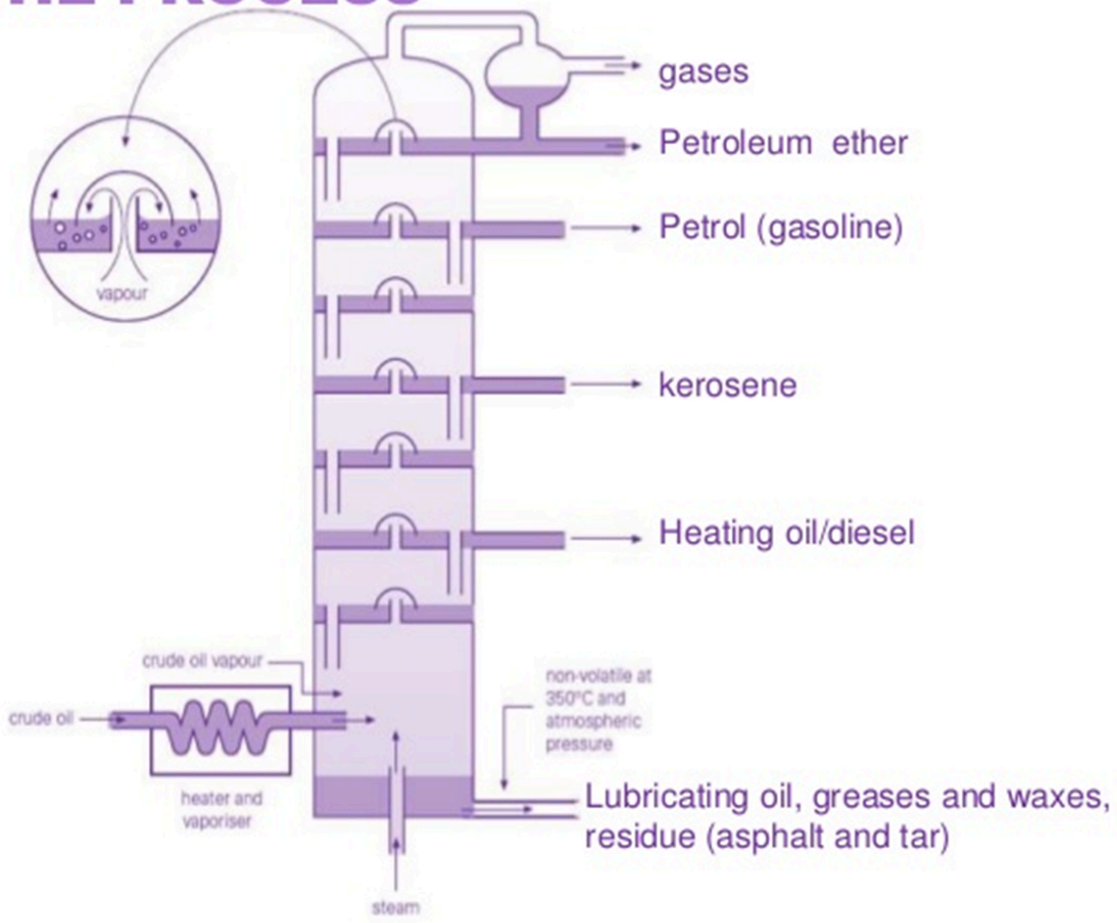


Crude oil must undergo several separation processes so that its components can be obtained and used as fuels or converted to more valuable products. The process of transforming crude oil into finished petroleum products (that the market demands) is called crude oil refining/ refining of petroleum.

1. **Seperation of water and Desalting**: The emulsified water along with the dissolved salts is removed by **passing** the crude oil **through highly charged electrodes** when the colloidal water droplets unite to form large drops which separate from the oil.
2. **Removal of Sulphur**: The crude oil is then **heated with CuO** to remove sulphur as CuS.
3. **Fractional distillation**: The principle of fractional distillation is that **vapours of higher boiling point compounds get condensed** into liquid during stepwise cooling.

Basically, crude oil has components with boiling points as high as 400. Oil is heated to that temperature and then the different boiling points' volatile matter are collected in different racks of the tower. The fumes collected are condensed and removed as liquids.

THE PROCESS


gases
Petroleum ether
Petrol (gasoline)
kerosene
Heating oil/diesel
vapour
crude oil vapour
crude oil
heater and vaporiser
non-volatile at 350°C and atmospheric pressure
Lubricating oil, greases and waxes, residue (asphalt and tar)
steam

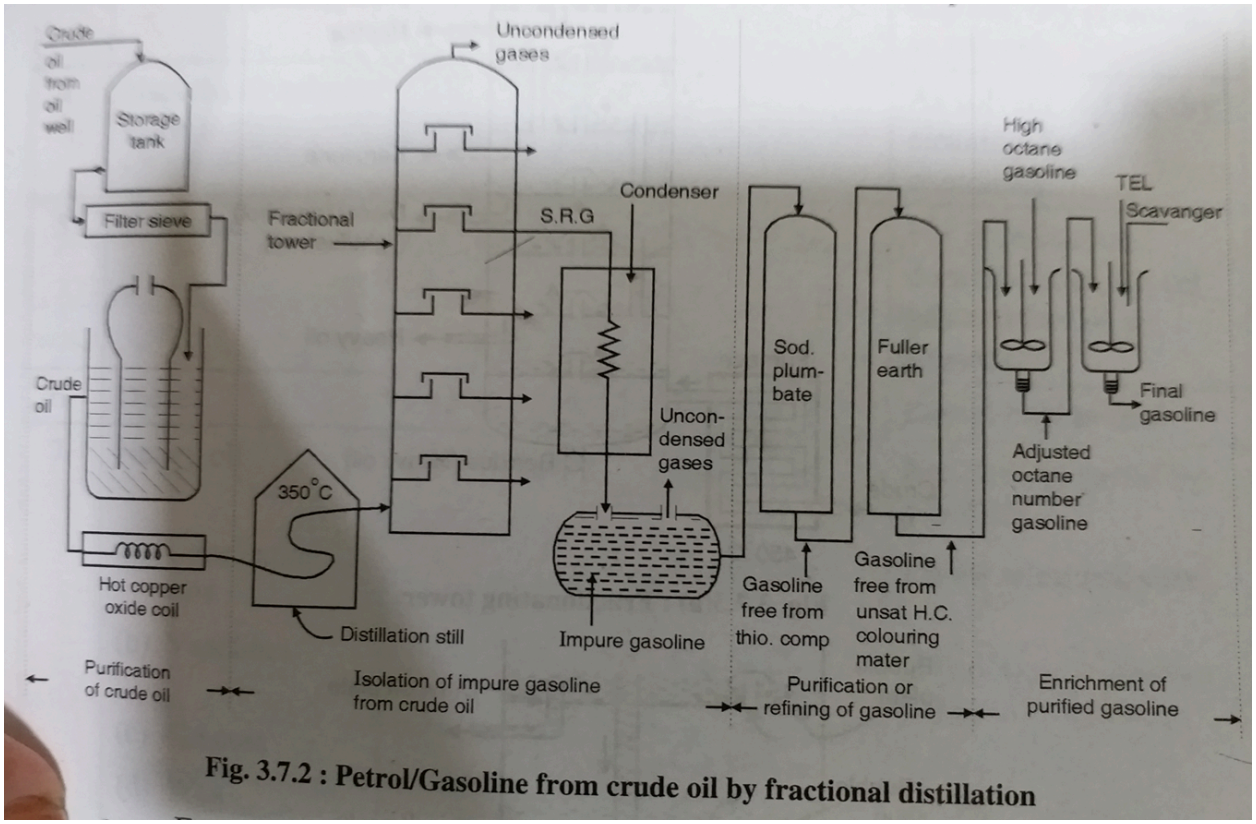
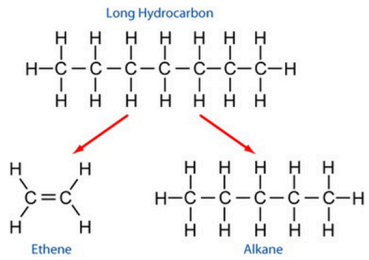


Fig. 3.7.2 : Petrol/Gasoline from crude oil by fractional distillation

Petrol is still very impure and less octane number. So we use more processes like TEL TML to purify it further.

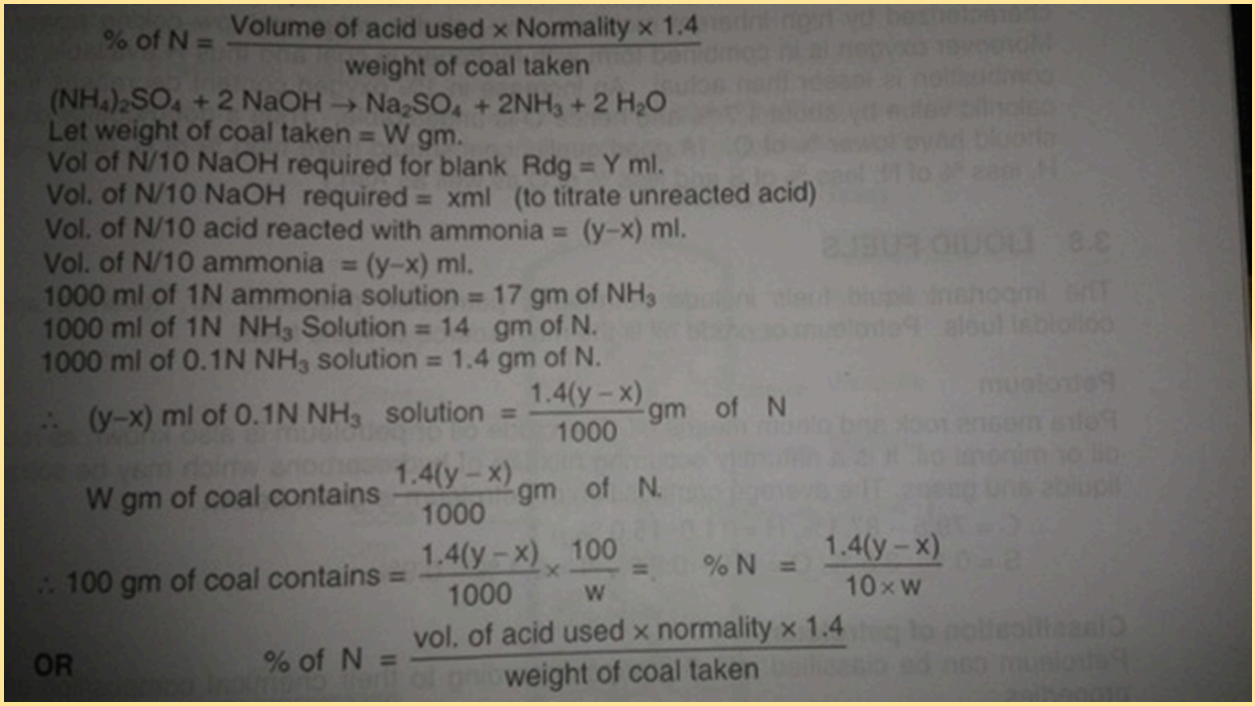
Crackling



Cracking is defined as a process, wherein **complex organic molecules** namely long chain hydrocarbons or kerogens **with high molecular weight** are **broken down** into **smaller molecules** namely light hydrocarbons with low molecular weight. It is caused by the **breaking of carbon-carbon bonds**.

4. A sample of coal contains C= 70%, O= 8%, N= 3%, S= 2% and Ash. If LCV is 8277.50Kcal/kg, find HCV and %H.
Solution: %H= 9.84 HCV= 8750.60 Kcal/kg

5. A sample of coal contains C= 61%, H= 6%, S= 0.5%, N= 0.2%, Ash= 0.3%. Calculate GCV and NCV.
Solution: %O= 32 GCV= 4250 Kcal/kg NCV= 3933.02 Kcal/kg



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

$(NH_4)_2SO_4 + 2\ NaOH \rightarrow Na_2SO_4 + 2NH_3 + 2\ H_2O$

Let weight of coal taken = W gm.

Vol of N/10 NaOH required for blank Rdg = Y ml.

Vol. of N/10 NaOH required = xml (to titrate unreacted acid)

Vol. of N/10 acid reacted with ammonia = (y–x) ml.

Vol. of N/10 ammonia = (y–x) ml.

1000 ml of 1N ammonia solution = 17 gm of NH_3

1000 ml of 1N NH_3 Solution = 14 gm of N.

1000 ml of 0.1N NH_3 solution = 1.4 gm of N.

$\therefore$ (y–x) ml of 0.1N NH_3 solution $= \frac{1.4(y-x)}{1000}$ gm of N

W gm of coal contains $\frac{1.4(y-x)}{1000}$ gm of N.

$\therefore$ 100 gm of coal contains $= \frac{1.4(y-x)}{1000} \times \frac{100}{w} =$ % N $= \frac{1.4(y-x)}{10 \times w}$

OR % of N $= \frac{\text{vol. of acid used} \times \text{normality} \times 1.4}{\text{weight of coal taken}}$

Numerical:

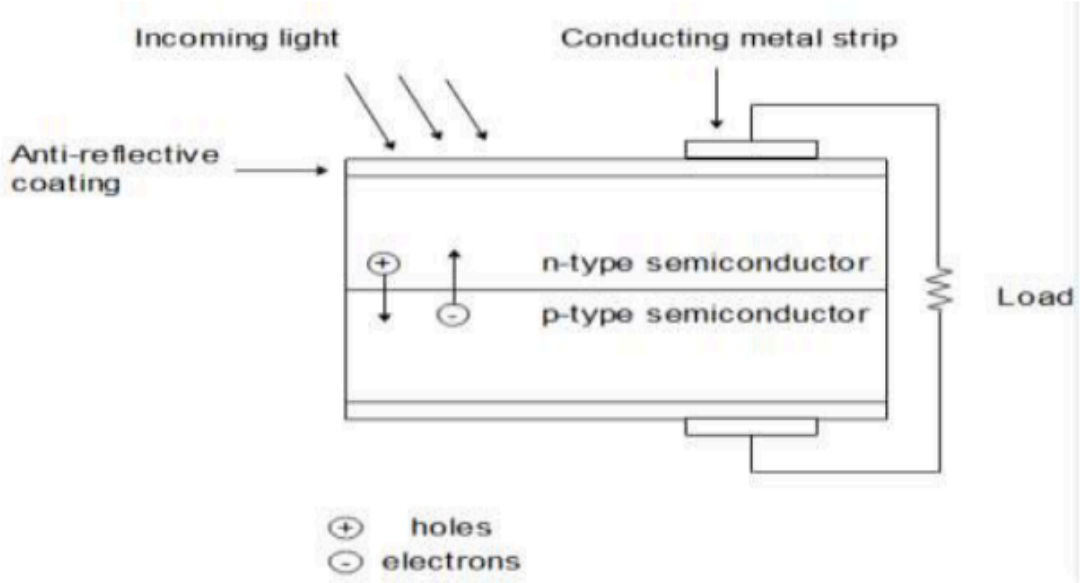
1. 0.2g of coal sample is burnt. The gaseous products are absorbed in potash bulb and calcium chloride tube of known weight. The increase in weight of potash bulb and calcium chloride tube are 0.66gm and 0.08gm respectively. Calculate %C and %H. (Solution: C= 90%; H= 4.44%)

2. 3gm of coal was heated in Kjeldahl's flask and ammonia formed was absorbed in 40ml of 0.5N acid. After absorption, the excess acid required 18.5ml of 0.5N KOH for neutralization. 2.3gm of same coal sample gave 0.35gm BaSO4 ppt. Calculate %N and %S. (N= 5.01%; S= 2.089%)

ENERGY SHORTNOTES

Renewable	Non renewable
Can be reused	Cannot
example	example
sustainable	Not sustainable/ exhaustible
Rate of renewal>rate of depletion	ulta
No pollution/ev friendly	Pollution

1. Form of energy that can be utilised repeatedly without the risk of putting the source to depletion is called sustainable energy.
2. Advantage of solar energy: non polluting, non depleting, renewable energy, available abundantly



3. pv cell diagram
4. • Battery: It is a device consisting of two or more galvanic cells connected in series or parallel or both

Advantages of lithium ion battery

1. Lithium-ion batteries have a significantly low self-discharge rate as compared to the other type of batteries.
2. High energy density
3. High charging rate
4. Easy installation
5. Work efficiency under extreme conditions of temperature and pressure

Applications:

1. Solar power
2. Emergency backup or UPS
3. Marine performance