Coal and Petroleum

Man's quest for sources of energy is inexhaustible. Early man depended mainly on muscular energy and later began to use wind and flowing water as sources of energy. He learned the art of making and controlling fire. Fire became his source of light at night. He used fire for warmth and realized that cooked food tastes better than raw food. As civilization advanced, man started using fire in making weapons, pottery etc. Today, with the progress in science and technology, fuels have become indispensable to man.

Fossil Fuels

Fossil fuels are energy-rich, combustible forms of carbon or compounds of carbon formed by the decomposition of biomass buried under the Earth over millions of years**.**

Types of fossil fuels

- Natural gas
- Coal
- Petroleum

Source of energy of fossil fuels

Fossil fuels are non-renewable and the source of their energy is Sun. The energy from Sun is trapped and stored as chemical energy in plants (and then transferred to animals) is ultimately released as heat and light energy by the fossil fuels on burning.

Formation of fossil fuels

- It is believed that plants and animals that died due to various natural calamities like cyclones, floods, forest fires, earthquakes etc., got buried under soil sediments over a period of millions of years.
- The remnants of buried plant and animal matter (organic) got subjected to the action of anaerobic bacterial decomposition, at high pressure, temperature, absence of oxygen etc., under the surface of the Earth.
- Due to the above conditions the trapped organic matter got gradually decomposed to coal, petroleum and natural gas.

Fossil Fuels Coal

Coal is a fossil fuel mined from ancient deposits. It is a black mineral of plant origin which is chemically, a complex mixture of elemental carbon, compounds of carbon containing hydrogen, oxygen, nitrogen and sulphur.

Formation of coal Coal is believed to have been formed about 300 million years ago under the Earth by a process called carbonization.

Carbonization is the process of slow conversion of vegetable matter to coal under the Earth due to the action of high pressure, high temperature, anaerobic bacteria and absence of oxygen.

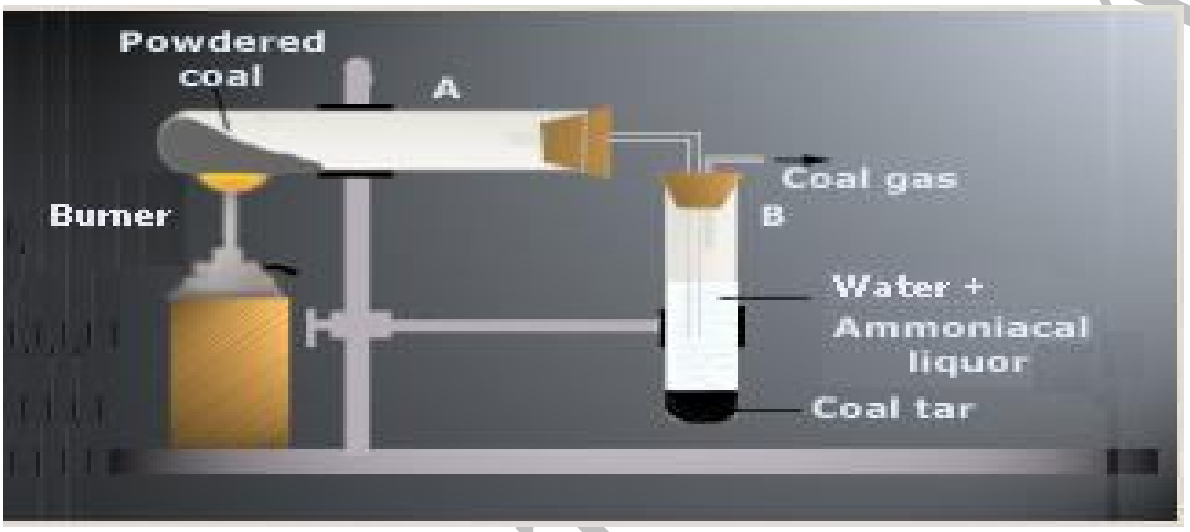
Classification of coal

Types of coal Depending upon the extent of carbonization, coal can be classified into four types as follows:

Type of coal	Carbon content	Commonly known as
Peat	11%	-
Lignite	38%	Soft coal / brown coal
Bituminous	65%	Household coal
Anthracite	96%	Hard coal

Peat is the first stage in the conversion of vegetable matter to coal while anthracite is the last.

Destructive distillation of coal



Destructive distillation of coal (Coking of coal)

The process of heating coal in the absence of oxygen to obtain useful products is called destructive distillation of coal.

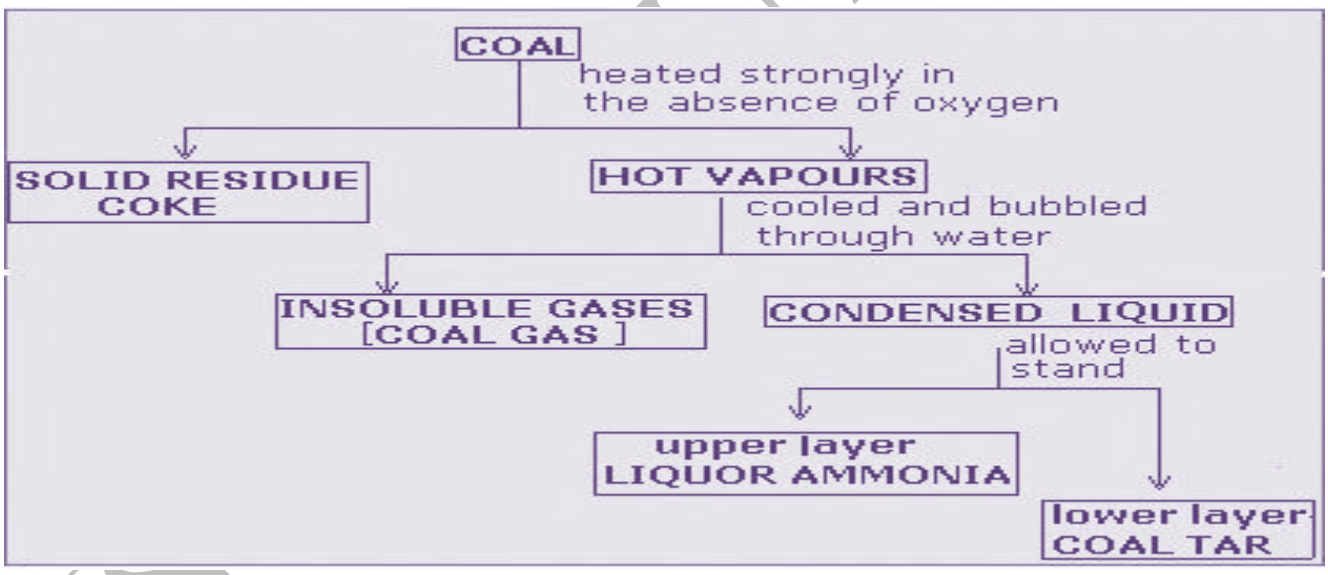
Laboratory method of destructive distillation of coal
Aim --- Destructive distillation of coal
Materials required ------ Two hard glass test tubes marked A and B, delivery tubes, clamp stand, burner, rubber stoppers, pieces of coal and water.

Principle --------- The volatile matter present in coal escapes on heating coal to a high temperature in the absence of oxygen.
Procedure
- Small pieces of coal are taken in test tube A.
- Test tube A is fitted with a rubber stopper carrying a delivery tube and is clamped to the clamp stand.
- Test tube B containing water is clamped vertically to the clamp stand.
- The apparatus is assembled as shown in the figure.
- The burner is lighted and the test tube A is heated first gently and then intensely. The following products are formed.

Products formed and their uses

Product	Formed/collected in	Uses
Coal Tar (complex mixture of carbon compounds)	Bottom of the test tube B. Liquid residue insoluble in water	Can be distilled to obtain: Benzene – solvent Toluene – manufacture of explosive TNT Naphthalene – insect repellent
Coal gas (CH_4+CO+H_2)	Combustible gas insoluble in water. Escapes through the side tube	Industrial fuel
Liquor ammonia (NH_4OH)	Soluble in water present in test tube	Manufacture of nitrogenous fertilizers
Coke (98%C)	Solid residue left behind in test tube A	i) Reducing agent in metallurgy ii) Manufacture of water gas and producer gas – Industrial fuel

Flow chart of the process taking place in a coking plant (same as destructive distillation)



Flow chart of the process taking place in a coking plant

Uses of coal

On destructive distillation, coal yields useful products like coal gas, coal tar, ammonia and coke. Generation of electricity Domestic fuel for cooking and heating Manufacture of synthetic petroleum and natural gas To heat water in steam engines and boilers Coal is thus regarded as the backbone of our national economy.

Petroleum

Petroleum is a dark, viscous, foul smelling liquid, a mixture of solid, liquid and gaseous hydrocarbons with traces of salt, rock particles and water.

Composition : Complex mixture of hydrocarbons, chiefly alkanes.

Formation

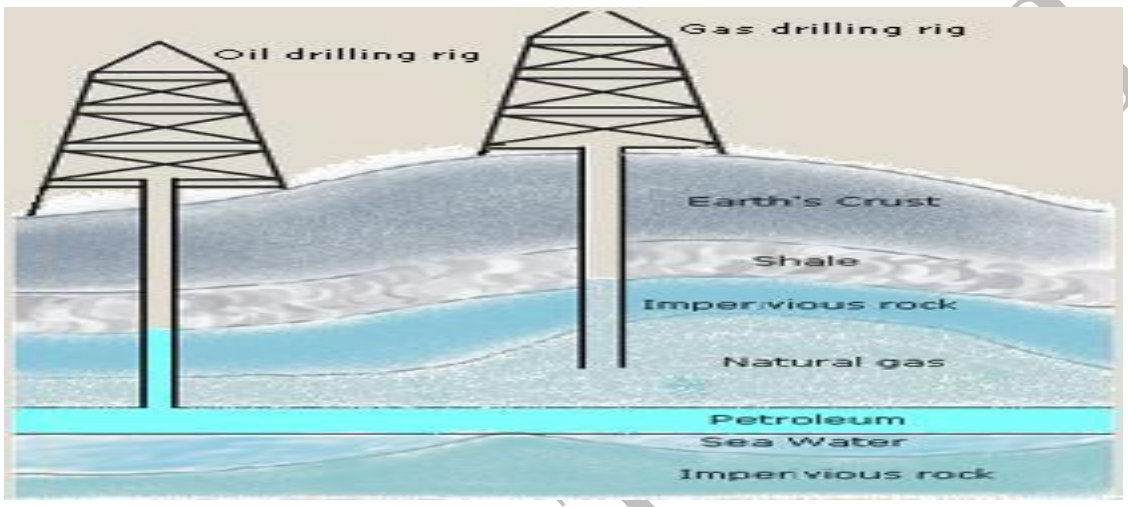
Petroleum is believed to have been originated from the remains of sea organisms. The micro organisms have largely contributed to the formation of petroleum. Due to the effect of heat, pressure and catalytic action of anaerobic bacteria, the buried remains of sea organisms decomposed very slowly forming petroleum.

Occurrence of petroleum

Petroleum occurs in nature, trapped between two layers of impervious (non-porous) rocks, usually under the sea. Natural gas collects above the surface of petroleum.

Mining of petroleum

Petroleum is brought to the surface by drilling a hole in the Earth's crust and sinking pipes deep down through the impervious cap rock. Natural gas first comes out under high pressure. Then, petroleum is pumped out, collected in tanks and transported, for further processing.



Occurrence and production of petroleum

Refining of petroleum

Meaning

Separation of petroleum into simpler fractions after the removal of unwanted materials.

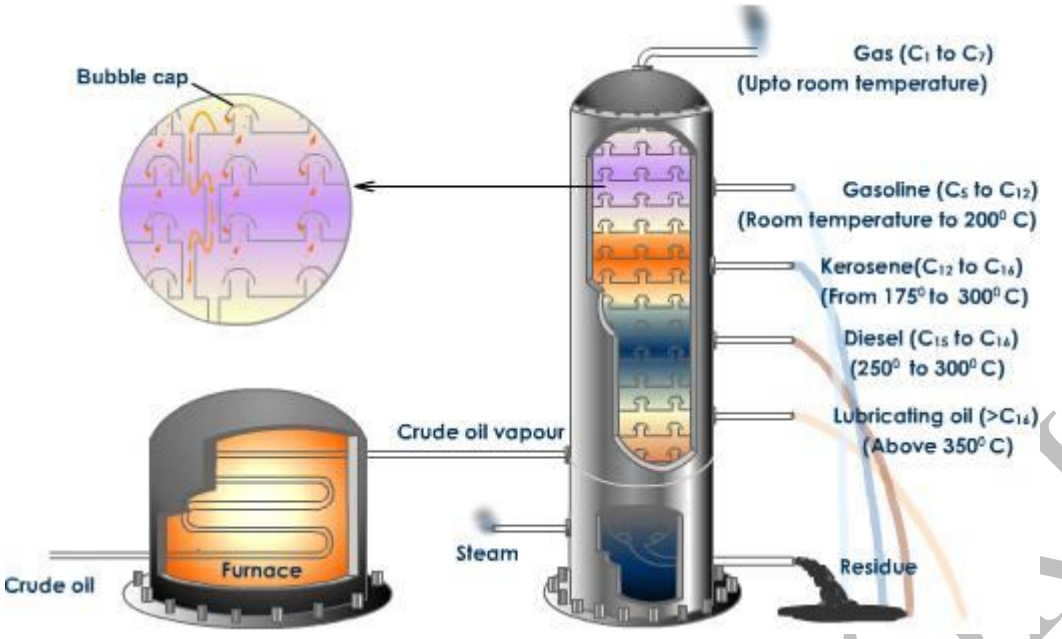
Method used

Fractional distillation in a fractionating column.

Principle

Difference in the boiling points of the various fractions of petroleum.

Construction of the fractionating column



Fractionating Column

The fractionating column is a tall steel tower attached to an electrically heated furnace. Throughout the length of the tower, there are trays with raised holes covered with loose fitting caps called the bubble caps. These caps allow the vapours to rise up and not descend down. The tower has outlet pipes at various levels along it's length.

Process

- Crude petroleum is pumped into the furnace where it is heated to a temperature of about 400°C. Petroleum is converted to vapours in the furnace.

- The vapours of petroleum are fed into the fractionating column from the bottom.

- As the vapours enter the column, they rise up and gradually get cooled.

- At the bottom of the furnace, the temperature is about 400°C. Here, the component that has a boiling point close to 400°C condenses (liquifies) first and is collected on the tray. From the tray it is let off through the outlet pipe.

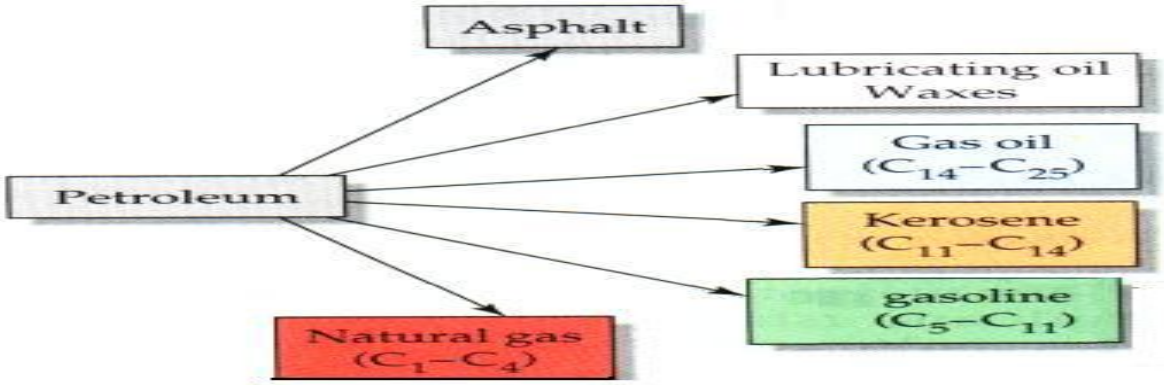
- The remaining vapours rise up through the bubble caps.

- When the vapours reach a particular height in the tower, the fraction that has a boiling point close to the temperature at that height condenses on the tray. The remaining vapours continue to rise upwards.

- Like this, at different levels in the tower, different fractions get condensed, collect on the trays and flow out of the outlet pipes.

The following table shows the boiling ranges and uses of some fractions of petroleum:

Fractions	Boiling range	Uses
Petroleum gas	< 40^0C	1. Domestic fuel (LPG) 2. Production of H_2 3. Production of carbon block
Petrol	40 – 170^0C	1. Fuel for light motor vehicles 2. Solvent for dry cleaning
Kerosene	170 – 250^0C	1. Domestic fuel - stoves 2. Illumination – lamps 3. Aviation fuel (for aeroplane) (purified)
Diesel	250 – 350^0C	1. Fuel for HM vehicles (Lorry, Bus) 2. Generating electricity
Fuel oil	350 – 400^0C	1. Industrial fuel 2. Fuel for ships
Lubricating oil (Residual oil)	> 400^0C	1. For lubricating machine parts.
Paraffin wax (residual oil)	> 400^0C	1. Fuel in candles 2. Shoe polish



Note:

- Residual oil is that component of petroleum, which is collected first at the bottom of the tower. It has a boiling range of over 400^oC. It can be further distilled separately to obtain lubricating oil, paraffin wax, asphalt etc.

- Most fractions of petroleum are fuels.

- Asphalt, lubricating oil and petroleum jelly are not used as fuels.

Synthetic petroleum

Preparation can be represented as follows:

$$\text{powdered coal (dissolved in solvents)} + \text{Hydrogen} \xrightarrow[\text{high pressure}]{\text{high temp}} \text{synthetic petroleum}$$

Synthetic petroleum is also a mixture of several alkanes. It is fractionally distilled to obtain petrol, diesel etc.

Heavy oil, a fraction of petroleum that is inexpensive is the solvent used.

Synthetic natural gas

Preparation can be represented as follows:

$$\text{powdered coal} + \text{Hydrogen} \xrightarrow[\text{pressure catalyst}]{\text{high temp}} \text{synthetic petroleum (mainly } CH_4\text{)} + \text{residue}$$

Pollution caused due to combustion of coal

Coal is mainly elemental carbon with small amounts of hydrogen, oxygen, sulphur and nitrogen.

On complete combustion of coal, carbon dioxide is the main product formed. This is non-toxic, but contributes to the green house effect if produced in excess.

Small amounts of oxides of nitrogen and oxides of sulphur formed are responsible for acid rain.

On incomplete combustion of coal, carbon monoxide and unburnt carbon particles are also formed. This causes carbon monoxide poisoning and formation of smog, blackening of buildings etc.

Pollution caused due to combustion of petroleum products

Petroleum is a mixture of hydrocarbons. On combustion, it produces mainly carbon dioxide and water vapour.

However, on incomplete combustion, they produce carbon monoxide, unburnt hydrocarbons etc. They also produce oxides of nitrogen.

Petrol is an important fraction of petroleum used in motor vehicles. To increase the efficiency of petrol engines, an anti-knock agent, lead tetra ethyl is added to slow down the rate of combustion.

Lead tetra ethyl releases harmful lead compounds into the atmosphere. Lead being a cumulative poison, is extremely toxic.

Pollution - A summary

Fossil fuel	Pollution formed	Harmful effects
1. Coal	Carbon monoxide Oxides of sulphur Oxides of nitrogen Unburnt carbon	Carbon monoxide poisoning Formation of smoke, smog.

From the above, we can infer that pollution caused by petroleum based fuels is more harmful than that of coal. Moreover, coal is generally used in a fixed place while petrol is used in vehicles which are constantly on the move. Thus, it is easier to control pollution due to combustion of coal as compared to that of petrol.