**Fuels:** The materials that are burnt to produce energy are called as **fuels.** These release energy in the form of heat and light. For example, wood, coal, charcoal, domestic gas, diesel, petrol etc.

**Classification of fuels:** Fuels are chiefly classified on the basis of their physical state, utilization and origin as explained under,

**a) Classification on the basis of physical state:** On the basis of physical state, fuels are classified as:

**i) Solid fuels:** Those fuels which are hard and compact and show characteristics of a solid are referred to as solid fuels. For example, wood, coal, charcoal, animal dung cakes, paraffin wax etc.

**ii) Liquid fuels:** Those fuels which show characteristics of a liquid are referred to as liquid fuels. For example, petrol, diesel, liquid hydrogen etc.

**iii) Gaseous fuels:** Those fuels which show characteristics of a gas are referred to as gaseous fuels. For example, LPG, natural gas, methane gas, coal gas, gobar gas, hydrogen gas etc.

**b) Classification on the basis of utilization:** On the basis of utilization, fuels are chiefly classified as:

**i) Primary fuels:** Those fuels which are directly used in the same natural form in which they exist are referred to as primary fuels. For example, wood, coal, charcoal, animal dung cakes, agricultural wastes etc.

**ii) Secondary fuels:** Those fuels which are not directly used as fuels, as they do not exist independently in nature but are prepared from the primary fuels are referred to as secondary fuels. For example, coal gas, gobar gas, water gas, wood, charcoal etc.

**c) Classification on the basis of origin:** On the basis of origin, fuels are classified as:

**i) Natural or Raw fuels:** Those fuels which occur naturally and can be used directly in the same natural form in which they exist are referred to as natural or raw fuels. For example, wood, coal, charcoal, animal dung cakes, agricultural wastes etc.

**ii) Manufactured or Processed fuels:** Those fuels which do not occur independently in nature bur are present in natural fuels and can be prepared from them are referred to as manufactured or processed fuels. For example, petrol, diesel, kerosene, coal gas, etc.

**Advantages of liquid and gaseous fuels over solid fuels:** Some of the main advantages of liquid and gaseous fuels over solid fuels are listed as under:

i) Most of the liquid and gaseous fuels possess a high calorific or heat value than solid fuels.
ii) Most of the liquid and gaseous fuels possess a low ignition temperature than solid fuels and thus burn easily.
iii) Most of the liquid and gaseous fuels are easy to handle, store and transport than solid fuels.
iv) Most of the liquid and gaseous fuels produce very little or no smoke than solid fuels.
v) Most of the liquid and gaseous fuels leave fewer residues than solid fuels.

**Biomass as fuel:** Biomass is the term applied to living matter present in a given area. It includes carbonaceous compounds and is the oldest source of fuels. These fuels are used by man in many ways as biofuels such as wood, cattle dung, agricultural wastes etc. These can be directly burnt or converted first into a more useful fuel by gasification, pyrolysis, fermentation etc. For example, wood can be directly burnt to produce heat energy, but gasification of wood produces wood gas. Similarly, pyrolysis of wood produces charcoal and fermentation of wood produces ethanol.

**Advantages of using wood** or **Biomass as fuel:** Wood is used as a basic fuel in majority of villages because of the following advantages:

i) It is renewable and widely distributed source of energy.
ii) It can be easily harvested and collected by unskilled labour.
iii) It produces flames and can be used to heat large surfaces.
iv) It is non-resinous, non-smoky and free from offensive smells.

**Fossil Fuels:** A fossil is defined as any thing dug out of the earth, that provides an evidence of presence of organisms which lived in the past. Coal, petroleum and natural gas are formed by the decomposition of the remains of the prehistoric plants and animals buried deep under the layers of the earth, and are accordingly referred to as **fossil fuels.**

**Formation of Fossil Fuels:** During its formation, an entire organism or its parts often get buried in sand or mud. These, then decay and disintegrate leaving no signs of their existence. Infact, the harder parts of organisms after their death, settle down and are covered by sediments and subjected to extreme pressure and temperature of the earth converts them into fossil fuels, the process being referred to as **fossilization.**

However, sometimes rocks present structures resembling plant remains (mineral substances) crystallize and develop into patterns resembling the outlines of plants, these are referred to as **pseudo fossils.**

**Coal as a fuel:** Coal is a fossil fuel found deep in coal mines under the surface of the earth. It is a complex mixture of carbon, hydrogen, oxygen and may also contain small fractions of sulphur and nitrogen compounds. It is the most important source of energy and is therefore regarded as the backbone of the energy section of our country.

**Formation of coal:** Coal formation takes place deep under the surface of the earth. It requires decomposition of large no. of plants and trees buried deep under the layers of the earth millions of years ago. These were then converted into coal under the influence of high temperature and low pressure of the interior of the earth. All these chemical processes take millions of years and are collectively known as **carbonization.**

**Types of coal:** The chief types of coal found in India are listed as under:

- **i)** **Peat:** It is a product of carbonization containing only 60% of carbon.
- **ii)** **Lignite:** It is a soft form of coal containing nearly 70% of carbon.
- **iii)** **Bituminous:** It is an another product of carbonization containing nearly 80% of carbon. It is also known as *household coal.*
- **iv)** **Anthracite:** It is a hard form of coal containing upto 90% of carbon. It is the most superior quality of coal found in India.

**Uses of coal:** The important uses of coal are mentioned as under:

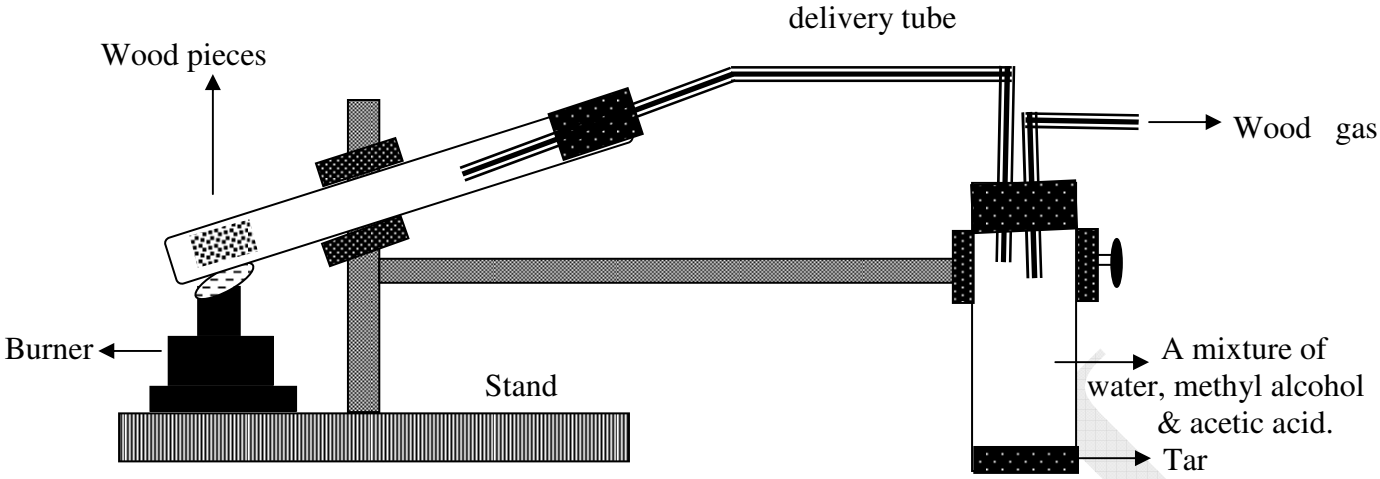
1. It is used as a domestic fuel for heating, lighting and cooking purposes.
2. It is used as a fuel in industries especially those engaged in metallurgy.
3. It is used in the production of the thermal electricity at the thermal electric power station.
4. It is used in the production of coke.
5. It is also used in the manufacturing of artificial or synthetic oil and synthetic gas.

**Destructive Distillation:** When a complex material containing compound of carbon is heated in a closed retort in absence of air or oxygen. It decomposes to produce a no. of simpler compounds and the process is referred to as **destructive distillation.**

**Destructive distillation of wood:** When wood is heated in a closed retort in absence of oxygen, it evolves a number of volatile materials and a black residue is left behind called as **charcoal** which on separation can be put into various uses.

**Experimental demonstration:** In laboratory, destructive distillation of wood can be performed by the under stated method:

Take two hard boiling glass tubes and put some pieces of dry wood in one tube. Fill the other tube with some water and arrange the two tubes on a stand as shown in the below figure. Join the two tubes with a delivery tube fitted with a cork. Fit another delivery tube in the test tube containing water.




Now start heating gently the glass tube containing wood pieces with the help of a burner. When it gets heated, a gas is evolved that passes through the delivery tube filled in with water and is called as **wood gas.** In addition, drops of deep black liquid are also found setting at the bottom of the tube containing water and are referred to as **tar.** However, methyl alcohol (wood alcohol) and acetic acid are also found mixed with water. A black residue is left behind in the parent test tube which is found to be charcoal.

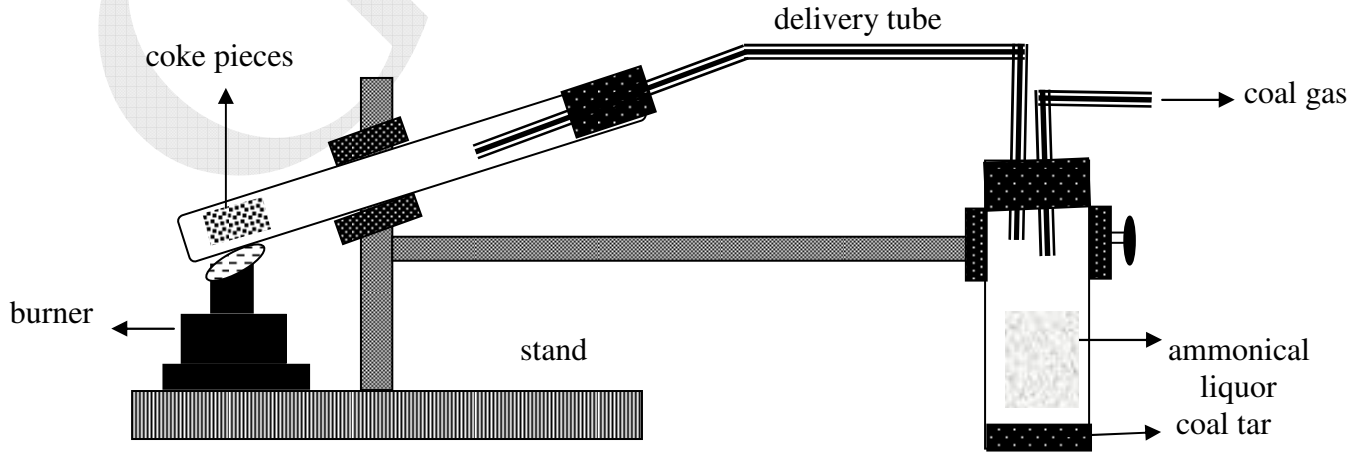
Thus to summarize, destructive distillation of wood procduces:

1. Charcoal (a black residual substance)
2. Wood gas (a combustible gas)
3. Methyl alcohol (wood alcohol)
4. Acetic Acid (vinegar)
5. Tar (a deep black liquid).

**Destructive distillation of coal:** When coal is heated strongly in a closed retort in absence of air, it evolves a no. of volatile materials and a black residue is left behind called as **coke** which on separation can be put to various uses.

**Experimental demonstration:** In laboratory, destructive distillation of can be performed by the under stated method.

Take two hard boiling glass test tubes and put some pieces of dry coal in one tube. Fill the other tube with some water and arrange the two tubes on a stand as shown below. Join the two tubes with a delivery tube fitted with a cork. Fit another delivery tube in the test tube containing water.n




Now start heating gently the test tube containing coal pieces with the help of a burner. When it gets heated, a gas is evolved that passes through the delivery tube into the test tube filled in with water and is called as

coal gas. In addition, drops of deep black liquid are also found setting at the bottom of the tube containing water and are referred to as coal tar. However, a gas called ammonia is also evolved in the process, which is mixed with water to form a mixture called ammonical lioquor. A black residue is left behind in the parent test tube called as coke.

Thus to summarize, destructive distillation of coal produces:

1. Coke (a black residual substance)
2. Coal gas (a combustable gas)
3. Ammonical liquor (a mixture of ammonia gas and water)
4. Coal tar (a deep black liquid)

**Coke:** It is a black residual substance obtained by the destructive distillation of coal. It contains 98% of carbon with hydrogen, oxygen and some other impurities.

**Uses of coke:** The chief uses of coke are mentioned as under:

1. It is used as an efficient fuel for heating, lighting and cooking purposes.
2. It is used in the metallurgical industries to extract iron from its ore.
3. It is used in the production of water gas, which is a mixture of carbon monoxide and hydrogen gas.
4. It is used in the production of producer gas, which is a mixture of carbon monoxide and nitrogen gas.
5. It is used in the production of number of organic compounds like aniline, benzene, toluene, anthracine etc.
6. It is used as an efficient reducing agent in industries and factories.

**Animal dung as fuel:** Animal dung can be used to produce heat either by making animal dung cakes and burning them in chulas or by converting it into biogas which can also be used as fuel. It is more worthy to prepare biogas from animal dung rather than using it directly as a fuel.

Biogas is obtained by anaerobic fermentation of animal wastes such as animal dung and plant wastes in presence of water bur in absence of air. In this process, the anaerobic bacteria (decomposers) act upon the carbonaceous compounds of plant and animal wastes and convert them into biogas.

Biogas is a gaseous mixture containing 65% of methane and carbondioxide, hydrogen and hydrogen sulphide. It is clean and efficient fuel which is economically cheap and easily available.

**Production of biogas:** Biogas is produced in a special plant called as biogas plant. It converts animal and plant wastes into a gaseous mixture called as biogas with the aid of anaerobic bacteria in presence of water but in absence of air and the process being referred to as anaerobic fermentation.

In India, biogas is produced on a large scale by two main types of biogas plants viz:

1. Floating gas holder type biogas plant
2. Fixed dome type biogas plant.

**Uses of biogas:** The chief uses of biogas are:

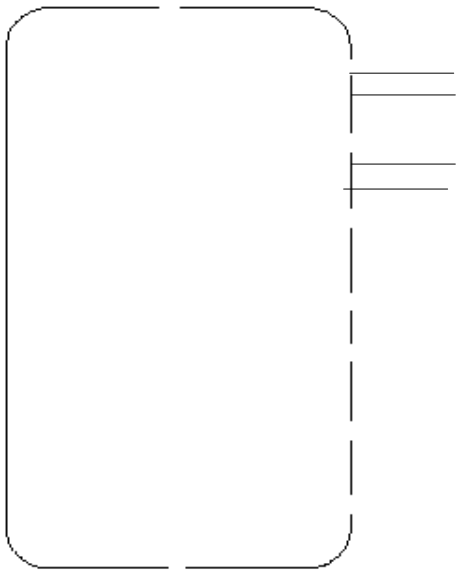
1. Biogas is used as a domestic fuel for cooking and heating purposes.
2. It is used for street lighting.
3. It is used as fuel for engines.

**Petroleum:** It is viscous, dark coloured liquid with foul smell. In fact, the word petroleum has been derived from two Greek words – "Petra" meaning *rock* and "Oleum" meaning *oil.* As it is formed under the earth between the layers of rocks, so called as petroleum. The petroleum obtained from the earth is a mixture of several solid, liquid and gaseous hydrocarbons mixed with water, salts and earth particles. It is lighter than water and insoluble in it.

**Formation of petroleum:** Petroleum occurs deep under the layers of earth. It is believed to be formed by the decomposition of organic matter buried under the oceans millions of years ago. During this process, microscopic organisms (plants and animals), entire or its parts, got buried un sand and mud. Most of these organisms after their burial decay and disintegrate leaving no sign of their existence. The chemical effect of the heat and pressure converted them into petroleum. Thus, petroleum so formed got trapped between

the layers of non-porous rocks (impervious rocks) forming an oil trap. From these layers, oil is obtained by drilling holes in the earth's crust and can be then used for specific purposes.

**Refining of Petroleum:** The petroleum obtained from the earth is in the crude form containing a mixture of several hydrocarbons with water, salts and earth particles. Before using it, petroleum is first refined in a specially designed tower called as **fractionating tower** and the process being referred to as **fractional distillation.**



In this process, the crude oil is first passed through a furnace having a high temperature of about $675^0$ K and the vapours formed are introduced into the fractionating tower. As the mixture of hot vapours rises through the tower, the vapours of the higher boiling point first condenses in the lower part of the tower and the lower boiling fractions rises up and condense in its upper part. The gases which don't liquidify are taken out from the top of the tower. The residue which don't vaporize is collected at the bottom of the tower and is subjected to further distillation to obtain more useful products.

The various fractions obtained by the fractional distillation of the crude petroleum oil are: petroleum gas, petrol (gasoline), propellants, kerosene oil, diesel oil, fuel oil, lubricating oil, paraffin wax, asphalt etc.

**Uses of fractions of petroleum:** The various fractions obtained by the fractional distillation of a crude petroleum oil and their uses are listed below:

**1. Petroleum gas:** It contains hydrocarbons having 1-4 carbon atoms per molecule. It is used as a fuel and in the production of carbon black. It is also used in the manufacture of gasoline.

**2. Gasoline:** It contains hydrocarbons having 5-10 carbon atoms per molecule. It is used as a fuel for lighting motor vehicles and solvents fro dry cleaning and in the making of petroleum gas.

**3. Kerosene:** It contains hydrocarbons having 10-12 carbon atoms per molecule. It is used as a house hold fuel for lighting and heating purpose and as an aviation fuel in a jet planes.

**4. Diesel oil:** It contains hydrocarbons having 12-15 carbon atoms per molecule. It is used as a fuel for heavy motor vehicles, pumps and diesel generators.

**5. Fuel oil:** It contains hydrocarbons having 15-18 carbon atoms per molecule. It is used as a fuel in industries to heat boilers and furnaces. It has replaced coal as it does not leave any residue after its combustion.

**6. Lubricating oil:** It contains hydrocarbons having 18-20 carbon atoms per molecule. It is used for lubrication of different machine parts.

**7. Paraffin wax:** It contains hydrocarbons having 20-30 carbon atoms per molecule. It is used in making of candles, Vaseline, ointments, wax paper and grease.

**8. Asphalt:** It contains hydrocarbons having 30-50 carbon atoms per molecule. It is actually a black residue left behind in the process. It is used for making roads and a number of organic compounds like benzene, toluene, aniline and anthrcine etc.

**Combustion of fuel:** The process of burning of a substance in presence of air to release heat and light energy is known as **combustion.** It is an exothermic reaction in which heat energy is liberated out. For example, when carbon is combusted in presence of air, carbon dioxide and a lot of heat energy is liberated as shown under in the example:

$$\underset{\text{Carbon}}{C} + \underset{\text{Oxygen}}{O_2} \longrightarrow \underset{\text{Carbon dioxide}}{CO_2} + \text{Heat}$$

Similarly, when methane is burnt in presence of air, it forms carbon dioxide, water vapour and a lot of heat energy is released out as shown in the example:

$$\underset{\text{Methane}}{CH_4} + \underset{\text{Air}}{O_2} \longrightarrow \underset{\text{Carbon dioxide}}{CO_2} + \underset{\text{Water vapour}}{2H_2O} + \text{Heat}$$

**Conditions necessary for combustion:** The combustion requires three basic conditions:

1. Presence of combustible substance
2. Presence of supporter of combustion.
3. Attainment of ignition temperature.

**Combustible substance:** A substance that burns or catches fire easily are referred to as **combustible substance.** These include substance like wood paper, cloth, kerosene, petrol, alcohol etc.

**Supporter of combustion:** A substance which causes a combustible substance to catch fire and burn is referred to as **supporter of combustion.** Eg, Oxygen is a supporter of combustion i.e. the process of combustion continues only in the presence of oxygen and if the supply of oxygen is cut off, the process of combustion stops.

**Ignition temperature:** The minimum or lowest temp. at which a substance catch fire and starts burning is referred as **the ignition or kindling temperature** of that substance. The process of combustion requires that every substance must be heated to its ignition temp., so that it catches fire and starts burning.

**Types of combustion:**

1. **Slow combustion:** It is type of combustion which proceeds at a very slow rate and liberates heat and light energy in a very minute quantity difficult to realize. For example, rusting of iron in a cellular respiration.
2. **Rapid combustion:** It is a type of combustion which proceeds at a faster rate and continues only as long as the fuel is available. The moment the supply of fuel is cut off, the process of combustion also stops. Eg, the burning of kerosene in kerosene stove, the burning of LPG in a gas stove.
3. **Spontaneous combustion:** It is type of combustion which take place at a room temperature. Eg, burning of yellow phosphorus when exposed to open air.
4. **Explosion:** It is a special type of rapid combustion in which the combustion of the fuel take place at a much faster rate and is characterized with the production of sound and flash of light. Eg, the burning of fire crackers, etc.

**Characteristics of an ideal or a good fuel:**

1. It should have a high calorific or a heat value, so that it can produce maximum energy by low fuel consumption.
2. It should have a proper ignition temperature, so that it can burn easily.]
3. It should not produce harmful gases during combustion.
4. It should be cheap in cost and easily available in plenty for everyone.
5. It should be easily and convenient to handle, store and transport from one place to another.
6. It should not be valuable to any other purpose than as a fuel.
7. It should burn smoothly and should not leave much residue after its combustion.

**Calorific or heat value of a fuel:** The amounts of heat energy produced by burning a unit mass of fuel completely is known as **calorific or heat value** of that fuel. It is expressed in **Kilo joules/gram**, which is written as **KJ/gm** or **$KJgm^{-1}$.** For example, when one gram of dry wood is burnt completely, 17 KJ of heat energy is liberated out. Thus, calorific value of wood is 17 KJ/gm.

The calorific or heat value of some of the commonly used fuels is given under:

| | |
|---|---|
| 1. Animal dung cakes | 7Kj/gm |
| 2. Wood | 17 Kj/gm |
| 3. Coal | 30 Kj/gm |
| 4. Charcoal | 33 Kj/gm |
| 5. Diesel oil | 45 Kj/gm |
| 6. Kerosene oil | 48 Kj/gm |
| 7. Petrol | 50 Kj/gm |
| 8. Butane (LPG) | 50 Kj/gm |

**Distinguish between combustion and respiration:**

| Combustion | Respiration |
|---|---|
| 1. It is a fast process. | 1. It is a slow process. |
| 2. It takes place at a high temp, which is equal to the ignition temperature of that substance being combusted. | 2. It takes place at a low temp. equal to the body temperature of that organism. |
| 3. It takes place outside the body of an organism. | 3. It takes place within the body of an organism. |
| 4. It is an incomplete process as some residual matter is left behind. | 4. It is a complete process as nothing is left behind as residue. |
| 5. Harmful gases like Carbon monoxide can be produced. | 5. No harmful gases are produced. |

**Natural Gas:** Natural gas contains 95% of methane and rest 5% of ethane and propane gases. It occurs in the earths crust along with the oil above the petroleum deposits. Natural gas is formed by slow decomposition of organic matter by anaerobic bacteria in absence of oxygen. It is obtained by drilling holes in the earth's crust and is supplied to long distances through pipelines for domestic and industrial purposes.

**Uses of Natural gas:** The chief uses of natural gas are:

1. It is used as domestic and industrial fuel for heating and lighting purposes.
2. It is used as a source of hydrogen gas in the making of fertilizers.
3. It is used as a source of carbon in tyre industries for making various types of tyres.

**Petroleum gas and LPG:** Petroleum gas is a mixture of ethane, propane and butane. The chief component being butane. All these constituents are gases at ordinary temperature, but can be easily liquidified under

pressure and the liquidified gas obtained is called as **liquidified petroleum gas** or **LPG**. It consists mainly of butane and smaller proportions of ethane and propane. This gas is then filled into the cylinders and supplied for domestic use because of its high calorific value and low ignition temperature. However, before filling it, a substance called as Ethyl Mercaptan ($C_2H_5SH$) is added to it as a smelling agent in order to detect its leakage.

**Advantages of LPG:** The main advantages of LPG are listed as under:

1. LPG burns with a smokeless flame.
2. LPG is easy to handle, store and transport from one place to another.
3. LPG has high calorific value and produces a great quantity of heat energy.
4. LPG has low ignition temperature so it burns in a moment's notice.
5. LPG does not produce any kind of harmful or poisonous gas during burning.

**Synthetic petroleum or Synthetic oil:** Synthetic fuel refers to the petroleum prepared by artificial methods. It was first prepared in Germany by Bergius in 1913.

In this process, a powdered coal is mixed with a hot solvent like oil and the paste obtained is heated with hydrogen gas at a high temp. of $250^0$C in presence of a catalyst. Under these conditions, coal gets hydrogenated to produce a liquid resembling the petroleum oil as represented under:

$$\text{Coal} + \text{Oil} + \text{Hydrogen gas} \xrightarrow{\text{Catalyst}} \underset{\text{(Synthetic Petroleum)}}{\text{Crude Oil}}$$

**Synthetic natural gas:** A synthetic natural gas refers to the natural gas prepared by artificial methods. It is usually prepared by the catalytic hydrogenation of coal. In this process, finally powdered coal is heated with hydrogen gas under pressure and in presence of a stable catalyst to obtain methane gas as one of the product which is the major constituent of a natural gas as represented under:

$$\text{Coal} + \text{Hydrogen gas} \xrightarrow[\text{Catalyst}]{\text{heat / pressure}} \text{Methane} + \text{other products}$$

**Pocket fuels or Rocket propellants:** Rocket fuels are special fuels, which are highly compact, possessing a very high calorific value. These burn rapidly and leave no residue. These include fuels like liquid hydrogen, synthetic rubber (Thiokol), liquid ammonia, alkyl hydrogen, methyl hydrogen, kerosene oil, paraffin wax, and cellulose base comp0ounds.

The rocket fuels require an oxidizing agents for their combustion such as liquid oxygen, liquid fluorine, hydrogen peroxide, dinitrogen tetraoxide, nitric acid, a nitrate, a chlorate or a flourate etc.

## TEXTUAL QUESTIONS

**Ans 3.** Charcoal is considered to be a better fuel than wood because of its following features:

1. It has a higher calorific value than wood.
2. It has a low ignition temp. than wood.
3. It produces less smoke than wood.
4. It is easy to handle, store and transport from one place to another.
5. It is convenient to use than wood.

**Ans 4 c.** Respiration is a process in which an organism breaks down food molecules (glucose) by burning it in presence of oxygen taken in during breathing to liberate energy required for maintaining and carry out the vital life processes. It also produces carbon dioxide and water as byproducts of the process. The process of respiration proceeds slowly at a low temp. equal to the body temperature of an organism. It takes a few hours to oxidize food molecules completely and as such referred to as slow combustion.

**Ans 4 d.** In a lamp, kerosene burns with a yellowish flame because of the presence of unburnt carbon particles left behind due to insufficient supply of oxygen. These carbonaceous particles rise up in the flame get heated and start glowing with a yellowish colour. However, in a wick stove, kerosene burns with a bluish flame because of the presence of the insufficient supply of oxygen.

**Ans 4 e.** Wood, cow dung cakes and agricultural wastes accounts for about 85% of the fuel for villages. However, due to scarcity of wood, cow dung cakes alone have became widely used fuel in most of the villages. But, animals dung is also important for agricultural purposes to maintain and increase fertility of the soil. So animals dung is used on a large scale in biogas plants, which not only fulfill the fuel requirements of the villages, but also keeps the animals dung available for agricultural purposes. It is only due to the biogas plants that animals dung can be put to best use both for fuel purposes and for agricultural programmes. These two reasons collectively assigned biogas plant as a boon to farmers.

**Ans 4 f.** Methane is a hydrocarbon with a molecular formula of $CH_4$. In every methane molecule, each carbon atom is bounded to four hydrogen atoms, which upon combining with oxygen produces a large amount of heat energy. On the other side, butane possesses a molecular formula of $C_2H_6$ and here each carbon atom is bounded to three carbon atoms. Thus, it produces less amount of heat energy than methane on combustion. In addition, the percentage of hydrogen in methane, which has the highest calorific value is greater than the percentage of hydrogen in butane.

**And 4 g.** Air pollutants are formed by the burning of oil products. Oil products are more difficult to control than those produced by the burning of coal because when oil products are burnt, carbon dioxide, carbon monoxide, unburnt hydrocarbons and nitrogen oxides are released into the air. In addition, particles of some additives such as lead are also produced. All these particles are extremely toxic as these can further form highly poisonous and acidic gases, which are harmful to plants, animals and soil. However, on the other side, when coal products are burnt, only carbon dioxide and carbon monoxide are produced which are not as harmful as that of the products produced by burning of the oil products.

**And 4 d.** When fossil fuels like wood, coal, petrol are burnt, a large volume of gases like carbon dioxide, carbon monoxide and sulphur dioxide are evolved out. These gases accumulate in our immediate environment resulting in its pollution and degradation. An increased proportion of these gases in the atmosphere leads to considerable changes in the climate. At the same time, these gases can give rise to the formation of acidic gases like sulphuric acid, which upon mixing with rain water results in the formation of the acid rain. It is highly toxic to plants, animals and historical buildings. In addition, the presence of large amount of gases evolved disturbs the actual natural balance of the atmospheric gases and creates a condition not feasible and hospitable for the living organisms.