3 Carbon-based Fuels

We need energy to meet all our needs. We get this energy from various sources, such as coal, petroleum and water. When we use a source of energy, we say we have harnessed it.

Thermal Energy and Related Terms

Thermal energy, i.e., heat, is the most common form of energy that mankind has been able to use. Though thermal energy is obtained from nuclear reactions also (which you will read about in a later chapter), it is generally obtained from combustion.

> When a substance combines with oxygen giving out heat and light, the phenomenon is called combustion.

Thus, combustion involves the burning of a substance. But remember that every substance does not burn. Wood or coal burns, but glass or gold does not.

A substance that undergoes combustion is said to be combustible. For example, wood, coal, petrol, diesel, natural gas and petroleum gas are combustible substances.

> A substance that is burnt with a view to obtaining heat (or light) from it is called a fuel.

Thus, wood, coal, petrol, diesel, kerosene, etc., are all fuels. As all these contain carbon in the free or combined state, they are carbon-based fuels.

Supporter of Combustion

> A supporter of combustion is a substance whose presence is essential for the combustion of another substance.

For all those substances that burn in air, oxygen is the supporter of combustion. Carbon dioxide generally behaves as a nonsupporter of combustion, though it supports the combustion of magnesium. It is possible that carbon dioxide decomposes into carbon and oxygen first and then the oxygen supports the combustion of magnesium. Magnesium burns in steam also.

Ignition Temperature

Wood or coal is a fuel, but does it start burning on its own? No, it has to be heated with a flame and only then does it begin to burn. But once it starts burning, the reaction is so highly exothermic (i.e., so much heat is produced) that the whole piece of wood or coal burns. So, a fuel starts burning only when it is heated to a temperature called its ignition temperature.

> The temperature to which a substance must be heated before combustion takes place is known as its ignition temperature.

You will understand the significance of ignition temperature upon doing the following activity.

Activity Place a paper cup containing water on a flame. The water will become hot, but the cup will not burn. This is because the water takes away the heat from the cup and does not allow it to reach its ignition temperature.

Fig. 3.1 A paper cup containing water does not burn when placed over a flame.

Now, we can easily understand why

(i) fire is extinguished by water, and

(ii) a log of wood takes a longer time to start burning than wood shavings, when heated in a flame.

When water is poured over a burning substance, it absorbs heat from the substance. As a result, the temperature of the substance falls below the ignition temperature, and it stops burning.

A log of wood has a huge mass. So, when we heat it with a flame, the heat the log receives is dissipated through its bulk. And the log takes a long time to attain the ignition temperature. On the other hand, wood shavings, having a much smaller mass, attain the ignition temperature more readily. So, a log or a large piece of wood takes a longer time than wood shavings to start burning.

Calorific Value of a Fuel

> The amount of heat given out by 1 g of a fuel on complete combustion in air or oxygen is known as the calorific value of the fuel.

The term is derived from 'calorie', which is a unit of heat. In the SI system, however, joule is used as a unit of energy. In SI, the calorific value of a fuel is expressed in kJ/g.

The calorific values of some fuels are given in Table 3.1.

Table 3.1 Calorific values of some fuels

Fuel	Calorific value in kJ/g
Wood	17
Coal	25–33
Dung cake	6–8
Kerosene	48
Diesel	45
Petrol	50
LPG	50
Biogas	35–40
Methane	55
Hydrogen	150

(a)

(b)

Fig. 3.2 (a) Heat is dissipated in a large piece of wood and the ignition temperature is not easily attained. (b) The ignition temperature is easily attained by wood shavings, and they start burning readily.

Hydrogen has the highest calorific value. However, it is difficult to handle in the gaseous state as it forms an explosive mixture with air. In the liquid state, it is used as a fuel in spacecraft.

What Makes a Good Fuel?

Several factors are considered while choosing a fuel. Apart from its easy availability at a reasonable price, a good fuel should have the following characteristics.

1. It should have a high calorific value.
2. It should have a low ignition point, but not lower than room temperature.
3. It should not burn too fast or too slowly.
4. The combustion of the substance should not produce harmful substances like soot and poisonous gases.
5. No residues should be left on combustion.
6. It should be safe to store, handle and transport.

Hydrocarbons

Hydrocarbons constitute a big family of fuels.

Hydrocarbons are organic compounds that contain only carbon and hydrogen.

Hydrocarbons may contain small to large numbers of carbon atoms. They are classified into several types, and each type may be represented by a general formula. For example, a class of hydrocarbons called alkanes have the general formula $C_nH_{(2n+2)}$. Its first member ($n = 1$) is methane, whose formula is CH_4. Some other common examples of alkanes are ethane (C_2H_6), propane (C_3H_8) and butane (C_4H_{10}). Acetylene (C_2H_2) belongs to a different class of hydrocarbons.

Physical State

In nature, hydrocarbons are generally found as mixtures. For example, natural gas and petroleum are mixtures of hydrocarbons. Under ordinary conditions, among alkanes,

- the lower members (containing 1–4 carbon atoms) are gases,
- the higher ones (containing 5–17 carbon atoms) are liquids, and
- the still higher ones (containing more than 17 carbon atoms) are solids.

Table 3.2 Some hydrocarbon fuels

State	Fuel	Main constituent	Source
Gaseous	Natural gas	Methane	Petroleum wells
	Biogas	Methane	Anaerobic fermentation of cattle dung and domestic sewage
	Petroleum gas	Butane	Petroleum refining
Liquid	Petrol, kerosene, diesel	Mixtures of hydrocarbons containing 5–17 C atoms	Fractionation of petroleum
Solid	Paraffin wax	Mixture of hydrocarbons containing more than 17 C atoms	Fractionation of petroleum

From Table 3.2, we find that all the hydrocarbon fuels, except biogas, are associated with petroleum. So, we will discuss biogas here, and the other fuels in a later section along with petroleum.

Biogas

Biogas is obtained by the anaerobic fermentation of cattle dung and domestic sewage. Anaerobic fermentation is fermentation in the absence of air. A mixture of methane (CH_4), carbon dioxide (CO_2), hydrogen (H_2) and hydrogen sulphide (H_2S) is thus obtained, methane being the main constituent.

The fermentation takes place in an underground tank (made of bricks), called the digester. A slurry of cattle dung and water is fed

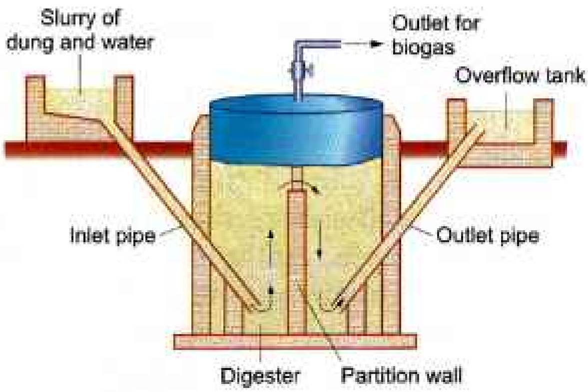

Fig. 3.3 Floating-dome biogas plant

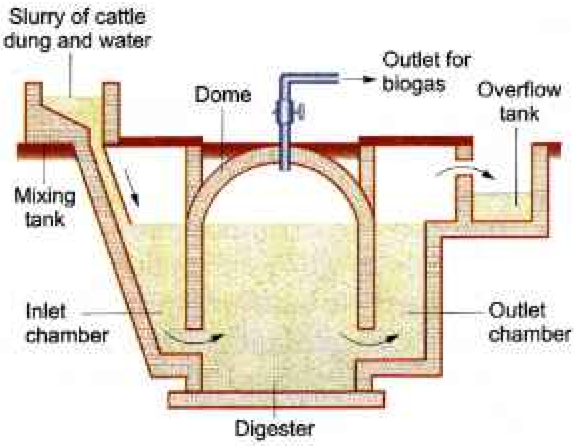

Fig. 3.4 Fixed-dome biogas plant

into the tank. On fermentation of the dung, biogas is evolved and collected in the gas holder (Figure 3.3) or the fixed dome (Figure 3.4).

The gas holder, made of steel, floats over the slurry. The holder moves up when gas collects in it and moves down when gas is drawn from it. (There is an outlet pipe for the gas on top of the gas holder.)

In the fixed-dome type, the gas collects under the fixed dome. When sufficient gas collects, it exerts pressure over the slurry and the slurry is forced into the outflow tank. The spent slurry obtained from the outflow tank is rich in nitrogen, phosphorus and potassium, and is used as a manure.

Larger plants can be established for a community where the cattle population is large. Such plants can be put up easily in rural India. The government subsidises and promotes the establishment of biogas plants through various agencies.

Apart from animal dung, biogas is obtained by a similar process from municipal sewage.

Combustion of biogas

Methane, the main constituent of biogas, burns to give carbon dioxide and water vapour. As methane contains only one carbon atom, it burns out completely. Thus no soot (unburnt carbon particles) or carbon monoxide is formed.

$$CH_4 + 2O_2 \rightarrow CO_2 + H_2O + \text{heat}$$

Fossil Fuels

You know that coal and petroleum are fossil fuels, and natural gas collects over petroleum in a petroleum well. Though their stocks are limited, they are the most widely used fuels of today.

Coal

Coal is the most widely found fossil fuel. It has been used from ancient times. It is obtained from mines by

- opencast mining, when the coal deposit is near the surface of the earth, and
- underground mining, when the deposit lies deep under the surface.

Of the total world reserves, more than half lie in North America and South America, one-third in Asia and the rest in other parts of the world. In India, coal is found mainly in West Bengal, Jharkhand, Orissa, Chhattisgarh and Madhya Pradesh.

Formation of coal

Millions of years ago, plants thrived in large, shallow swamps. They were buried under the earth owing to some natural phenomena, and fossilised in course of time. A combination of heat, pressure and bacterial action gradually converted these buried remains into coal. Plants contain carbon compounds. So, coal is mainly carbon.

Peat is the first stage of formation of coal. When the plants died, they fell into the swamps, and were covered by sand and silt. Below the water, they were decomposed by anaerobic bacteria, which do not require the presence of oxygen. This led to the formation of peat. (In contrast, when dead plants fall on the ground, they are decomposed by aerobic bacteria. The products then are liquid or gaseous.)

Because of earthquakes and volcanic upheavals, the remains of these plants and peat sank below the ground. Several such events occurred, and many layers of plant remains were deposited beneath the ground over millions of years. These layers, especially the lower ones, experienced tremendous pressure and temperature. Because of the high temperature and pressure, certain gaseous products including water vapour were driven out, and the carbon content in the plant remains increased. This process, as you know, is called carbonisation. This is how vast deposits of rocky carbon, called coal, were formed.

The type of coal formed depends upon

- the pressure and temperature to which the layer of plant remains has been subjected, and
- the time for which the plant remains have been buried.

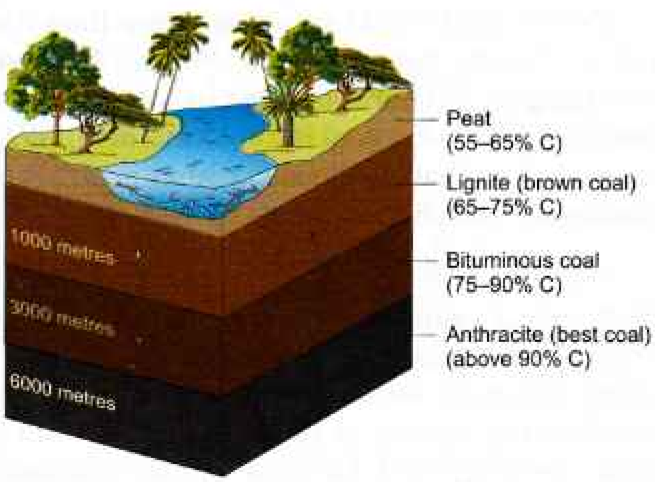

Fig. 3.5 Stages in which coal is formed

All these factors, in turn, depend upon the depth of the layer. Thus, four stages of the formation of coal have been identified—peat, lignite, bituminous coal and anthracite (Figure 3.5). It is natural that the extent of carbonisation, and therefore, the carbon content increases with depth. Anthracite is the best-quality coal and then come bituminous coal, lignite and peat.

Apart from carbon, coal contains nitrogen and sulphur as impurities.

The destructive distillation of coal

The destructive distillation of coal can be carried out just as that of wood (Figure 3.6). Some vapours are produced. A part of these vapours is condensed into coal tar and ammoniacal liquor on being cooled. The rest escapes as coal gas. A solid residue (coke) is left behind.

Coal gas Coal gas is a mixture of hydrogen, carbon monoxide and methane, all of which are combustible. So, coal gas is an important fuel. Previously, it was used for street lighting. It is still used in industries for several purposes.

$$2H_2 + O_2 \xrightarrow{\text{burn}} 2H_2O$$

$$2CO + O_2 \xrightarrow{\text{burn}} 2CO_2$$

$$CH_4 + 2O_2 \xrightarrow{\text{burn}} CO_2 + 2H_2O$$

Coal tar It is a thick, black liquid collected on the condensation of the vapours. It contains many organic compounds. The pitch obtained from coal tar is used in making roads.

Ammoniacal liquor It is a solution that collects over coal tar, and contains ammonium hydroxide. It is used for making fertilisers.

Coke Coke is the solid residue left behind in the process. It contains more than 98% carbon. It is used (i) as a reducing agent in metallurgy, and (ii) for producing fuel gases like water gas and producer gas.

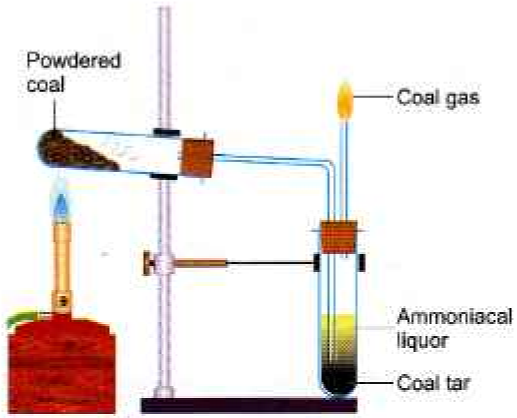

Fig. 3.6 The destructive distillation of coal produces coke, coal gas, coal tar and ammoniacal liquor.

Fuel gases from coke

Two industrially important fuel gases are obtained from coke.

Water gas You know that water gas is a mixture of carbon monoxide and hydrogen, obtained by passing steam over red-hot coke.

Producer gas Producer gas is a mixture of carbon monoxide and nitrogen. It is obtained by passing air over red-hot coke.

$$\underset{\text{coke (red hot)}}{2C} + \underbrace{O_2 + 4N_2}_{\text{air}} \rightarrow \underbrace{2CO + 4N_2}_{\text{producer gas}}$$

(Air contains one part by volume of oxygen and four parts by volume of nitrogen.)

Carbon monoxide is a combustible component of producer gas, and so producer gas is used as a fuel.

$$\underbrace{2CO + 4N_2}_{\text{producer gas}} + O_2 \xrightarrow{\text{burn}} 2CO_2 + 4N_2 + \text{heat}$$

Petroleum and Related Fuels

Petroleum is a thick, dark, strong-smelling liquid. It is a mixture of several hydrocarbons. So it is a great source of fuel. Unrefined petroleum is also called crude oil.

Petroleum is generally found deep under the earth, and wells are sunk to obtain it. Sometimes it oozes out from rocks too. The name petroleum has been derived from the Latin word *petra*, meaning rock, and *oleum*, meaning oil.

Reserves

Vast reserves of crude oil are found in Saudi Arabia, Kuwait, Iran, Iraq, Libya, Russia, China and the USA. In India, oil is found in Assam, Gujarat, Bombay High and the deltas of the rivers Kaveri and Godavari.

Refineries in India

In India, oil refineries are situated at Digboi, Haldia, Barauni, Mathura, Bharuch and Jamnagar.

Formation of petroleum

Petroleum is formed from the remains of marine animals and plants. Millions of years ago, dead marine organisms collected on the floor of the seas and were covered by sand and sediments. Many layers of such remains were formed, and the older ones went deeper in course of time. The remains were decomposed by bacterial action. A part of the products of decomposition was liquefied under tremendous pressure and temperature, and another part was converted into gaseous form. The liquid, called petroleum, seeped through porous rocks till it met nonporous rocks. Water had seeped earlier through the porous rocks, and petroleum formed its reservoir over the water. The gaseous product, called natural gas, collected over the petroleum. The process of formation took millions of years, and it still continues.

In course of time, oil may have seeped through rocks and some reservoirs changed location. Some seas too shifted. As a result, oil reserves are found not only under seas, but also under land.

The porous rocks are drilled with the help of an oil rig. When oil is struck, it gushes out due to the high pressure inside.

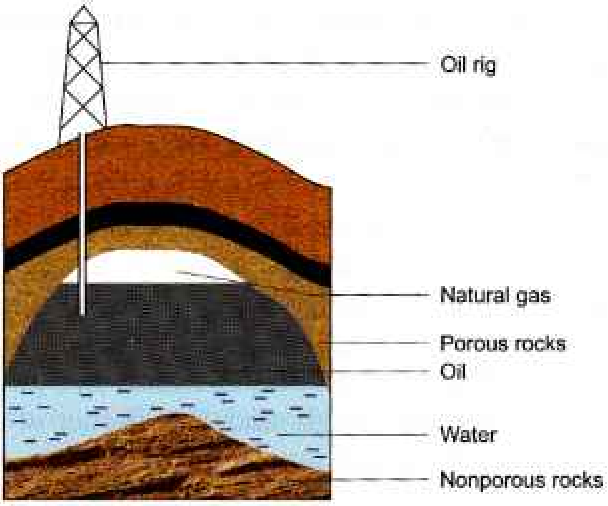

Fig. 3.7 Drilling for crude oil and natural gas

Natural gas also comes out, and can be directly transported through pipes and used. When the pressure inside reduces, the oil is pumped out. The crude oil is transported to oil refineries for processing.

Refining petroleum

Petroleum contains a large number of components—mostly hydrocarbons—with different boiling points. They are separated by fractional distillation. The separated parts, containing mixtures of hydrocarbons, are called fractions.

What is fractional distillation?

This is a special kind of distillation used to separate a mixture of two or more miscible liquids with different boiling points.

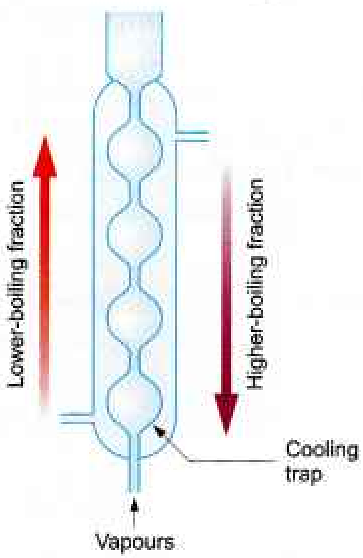

Fig. 3.8 A fractionating column

Consider a mixture of two such liquids. The vapours are passed through a vertical column, called fractionating column, with cooling traps. The vapours of the higher-boiling liquid condense first (i.e., in the lower part). The vapours of the lower-boiling liquid rise up and condense in the higher part or go out of the column. Methods can be devised to collect the fractions separately.

Fractional distillation is carried out in high steel towers in oil refineries. The crude oil is vaporised at about 400°C and the vapours are fed into the tower. As the vapours rise, they are cooled by shelves fixed to the tower. The fraction with the highest boiling point condenses in the lowermost region. The liquid collects in a cooling tray, and is led out. The lower-boiling components rise up the tower and condense in subsequent stages in decreasing order of boiling point.

The uncondensed gas, called petroleum gas, comes out of the tower. Petrol (gasoline), kerosene and diesel are the middle fractions. The residue left on boiling of the crude oil contains asphalt, paraffin wax and lubricating oil, which are separated again by fractional distillation.

The different fractions with their boiling range and uses are given in Table 3.3.

Table 3.3 Products of petroleum refining

Fraction	Boiling range	Uses
Petroleum gas	Below 40°C	Domestic fuel (LPG)
Petrol	40–170°C	Automobile fuel
Kerosene	170–250°C	Domestic fuel
Diesel	250–350°C	Fuel for automobiles, locomotives, generators, pumps and agricultural machinery
Fuel oil	350–400°C	Fuel for ships and industries
Lubricating oil (Residue)	Above 400°C	Lubricating machines
Paraffin wax (Residue)	Above 400°C	Making candles, pomades and grease
Asphalt (Residue)		Surfacing roads

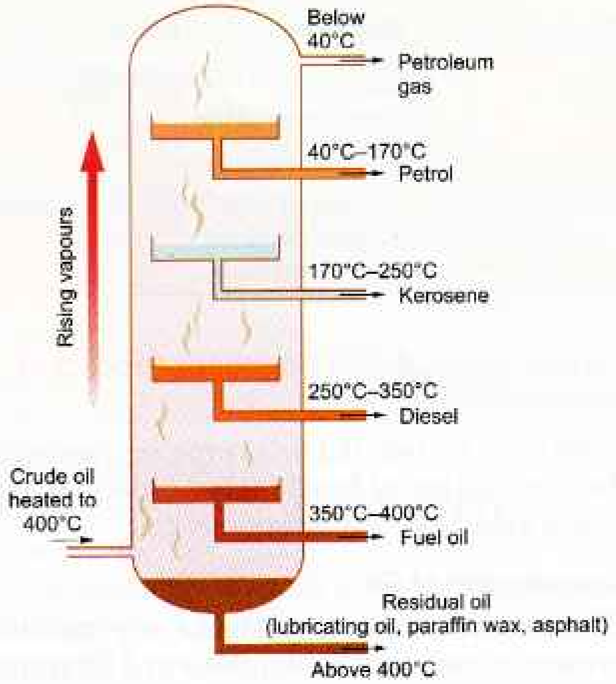

Fig. 3.9 Fractional distillation of petroleum

Some common fuels obtained from petroleum

Some common fuels obtained from the fractionation of petroleum are mentioned below.

LPG Petroleum gas, which comes out uncondensed from the fractionating tower, is liquefied and is known as *l*iquefied *p*etroleum *g*as (LPG). It is generally filled in cylinders to be used in kitchens or laboratories.

The main constituent of LPG is butane (C_4H_{10}), which burns without soot (black particles of unburnt carbon).

$$2C_4H_{10} + 13O_2 \xrightarrow{\text{burn}} 8CO_2 + 10H_2O + \text{heat}$$

Petroleum gas is colourless and odourless. So, a foul-smelling organic compound, named ethyl mercaptan, is added to LPG to enable one to detect its leakage from a distance.

Petrol, kerosene and diesel These are the common liquid fuels obtained from petroleum. They are mixtures of hydrocarbons containing 5 to 17 carbon atoms, petrol being the lowest-boiling and diesel being the highest-boiling fractions.

Paraffin wax Paraffin wax is a colourless solid fuel (with a melting range of 48°C to 66°C) obtained from petroleum. It is a mixture of hydrocarbons containing more than 17 carbon atoms, and is used for making candles. In a candle, the wax first melts and then gets partly vaporised by obtaining heat from the lighted wick. Finally, the vapours burn to give heat and light. Paraffin wax is also used in making pomades (e.g., Vaseline) and greases.

The candle flame If you observe a candle flame minutely, you will find that the flame consists of four regions:

(a) a bright blue region near the wick, where the hydrocarbon burns completely,

(b) the dark inner core containing unburnt vapours of wax,

(c) the luminous region containing unburnt carbon particles, and

(d) an outer mantle (not prominently visible) surrounding the entire flame.

In fact, all hydrocarbon flames have the same principal structure as the candle flame.

Fig. 3.10 The structure of a candle flame

Natural gas

As you know, natural gas is the decomposition product of marine organisms. It is found in petroleum wells. It is mostly methane, which burns completely, producing carbon dioxide and water vapour.

$$CH_4 + 2O_2 \xrightarrow{\text{burn}} CO_2 + 2H_2O + \text{heat}$$

As no soot is formed, methane is considered a very clean fuel. Compressed natural gas (CNG) is, therefore, preferred to diesel or petrol for use in motor vehicles used for public transport in some cities.

Products Obtained upon the Combustion of Fossil Fuels

On combustion of fossil fuels, we get products which are not environment-friendly. In these fuels, some nitrogen- and sulphur-containing compounds are also present. So, on combustion, these fuels also produce nitrogen dioxide (NO_2) and sulphur dioxide (SO_2), apart from other products like CO_2 and CO.

When petroleum fuels burn, the higher hydrocarbons break down to give lower hydrocarbons. If the combustion is incomplete, soot is also formed.

Table 3.4 Products obtained upon the combustion of fossil fuels

Product	How formed	Effect
Carbon dioxide	Combustion of carbon in fuels in a sufficient supply of air	Increase in greenhouse effect
Carbon monoxide	Combustion of carbon fuels in an insufficient supply of air	Air pollution
Nitrogen dioxide	Burning of nitrogen compounds	Air pollution and acid rain
Sulphur dioxide	Burning of sulphur compounds	Air pollution and acid rain
Hydrocarbons	Breaking down of higher hydrocarbons (petroleum fuels)	Increase in greenhouse effect
Soot	Incomplete combustion of the fuel	Air pollution
Water vapour	Burning of hydrocarbons (petroleum fuels)	No adverse effect

Carbon Monoxide—A Poisonous Product of Combustion

Carbon monoxide (CO), a common product of the combustion of fossil fuels—especially from motor vehicles—is a poisonous gas.

Concentration of CO

The concentration of a substance, expected to be present in very small quantities in a mixture, is often expressed in parts per million (ppm). This tells us the number of parts of a substance present in 1 million (1,000,000) parts of the mixture.

The concentration of CO in air is also expressed in ppm. For example, a CO level of 100 ppm in a congested city indicates that 100 litres of CO is present in 1,000,000 litres of air in that city.

The CO level in cities generally varies from 5 to 100 ppm.

How does CO affect us?

As you know, blood transports oxygen in our body. When we inhale air, the oxygen of the air combines with haemoglobin of the blood to form oxyhaemoglobin. Oxyhaemoglobin runs through blood vessels and gives up its oxygen to cells, which use it for respiration. But CO displaces oxygen from oxyhaemoglobin to form carboxyhaemoglobin. *The affinity of CO for haemoglobin is 325 times greater than that of oxygen.* So the displacement takes place easily. The formation of carboxyhamoglobin cuts off oxygen supply to cells, and adverse effects are seen. The severity of the symptoms depends on the amount of CO in the blood.

Inhaling air with a high CO level may even be fatal. A person may die if he or she sleeps in a closed room heated by a coal fire.

Table 3.5 Effects of CO poisoning

CO (ppm)	Effect
100	Headache, disorientation
300	Loss of consciousness
600	Coma
800	Death

Curing CO poisoning

Carboxyhaemoglobin slowly loses CO on being exposed to an excess of oxygen, and oxyhaemoglobin is again formed. So, a person suffering from CO poisoning should be kept on oxygen till he or she recovers.

Fighting Fire

Learning how to fight fire is extremely important as fire can wreak havoc. The following methods are used, depending on the nature of the fire.

Using Water

The oldest and the most common method to put out a fire is to throw water over the burning object. As you know, water cools the object to a temperature below its ignition point, which stops burning.

The method is, however, not effective if the fire is caused by petrol, kerosene or diesel. As these substances are lighter than water, they continue to burn over water.

If the fire is caused by an electrical short-circuit, water should be used only after the electric supply is cut off. This is because ordinary water conducts electricity.

Using Sand or a Sheet

A small fire or one caused by burning petroleum, kerosene or diesel can be put out by throwing sand over the burning object. This cuts off the contact of the object with air.

Similarly, when a person's clothes catch fire, he or she should be wrapped in a thick sheet in order to cut off the supply of air.

Using a Fire Extinguisher

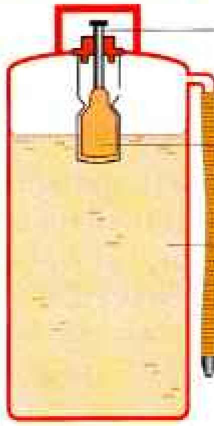

Fig. 3.11 A fire extinguisher

Common fire extinguishers produce carbon dioxide by the action of sulphuric acid on a solution of sodium carbonate or sodium hydrogencarbonate.

$$Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O + CO_2$$

$$2NaHCO_3 + H_2SO_4 \rightarrow Na_2SO_4 + \underbrace{2H_2O + 2CO_2}_{\text{gushes out}}$$

A solution of sodium carbonate or sodium hydrogencarbonate is placed in a fire extinguisher. A sealed bottle containing sulphuric acid is also placed there. In case of fire, the acid bottle is broken by striking the plunger against a hard surface. The acid reacts with the sodium carbonate or sodium hydrogencarbonate, and carbon dioxide is formed. A mixture of water and carbon dioxide gushes out, which is directed towards the burning object. Carbon dioxide, being heavier than air, surrounds the burning object and cuts off the supply of air. As a result, the fire is put out.

Fire Safety at Home

The following fire safety measures should be taken at home.

1. Fireproof materials should be used in the electrical wiring of the house. The electrical circuitry should be designed in such a way that the power supply to the house is automatically cut off in case of fire.
2. The plug points of electrical gadgets, e.g., the TV, audio system and computer, must be switched off when not in use.
3. The following safety measures must be taken in case LPG is used for cooking.
   (i) A good-quality stove or cooking range should be used.
   (ii) The connection tube should not be too old—the gas may leak.
   (iii) The valve fixed to the regulator must be closed when the stove is not in use.
   (iv) The kitchen must have a good exhaust system so that the gas does not accumulate in case of leakage.
4. A fire extinguisher should be installed in the house.
5. A couple of buckets containing sand should be kept at an easily reachable point in the house.

Points to Remember

- The temperature to which a substance must be heated before combustion takes place is known as its *ignition temperature*.
- The amount of heat given out by 1 g of a fuel on its complete combustion in air or oxygen is known as the *calorific value* of the fuel.
- *Hydrocarbons* are organic compounds that contain only carbon and hydrogen. They constitute a big family of fuels.
- Among a class of hydrocarbons called alkanes, the hydrocarbons containing
  (i) 1–4 carbon atoms are gases,
  (ii) 5–17 carbon atoms are liquids, and
  (iii) more than 17 carbon atoms are solids.
- Coal and petroleum are *fossil fuels*. Natural gas collects over petroleum in a petroleum well.
- Biogas (mostly methane) is obtained by the anaerobic fermentation (fermentation in the absence of air) of cattle dung or municipal sewage.
- The destructive distillation of coal produces coal gas, ammoniacal liquor and coal tar, and leaves a residue of coke. Coal gas is a very good fuel.
- Water gas and producer gas are industrial fuels obtained from coke.
- Water gas—a mixture of CO and H_2—is obtained by passing steam over red-hot coke.
- Producer gas—a mixture of CO and N_2—is obtained by passing air over red-hot coke.
- The fractional distillation of petroleum (also called crude oil) gives
  (i) petroleum gas, which on liquefaction, gives LPG,
  (ii) petrol, kerosene and diesel as liquid fuels, and
  (iii) paraffin wax as a solid fuel.
- Products obtained from the combustion of fossil fuels are carbon monoxide, carbon dioxide, nitrogen dioxide, sulphur dioxide, hydrocarbons, soot and water vapour.

- Carbon monoxide is a poisonous gas. It displaces oxygen from oxyhaemoglobin to form carboxyhaemoglobin. Thus the oxygen supply to cells is reduced or cut off.
- A patient suffering from carbon monoxide poisoning should be kept on oxygen till he or she recovers.
- We can fight fire by using water, sand or fire extinguishers.

Exercise

Short-Answer Questions

1. What are the following called?
   (i) A phenomenon in which a substance combines with oxygen, giving out heat and light
   (ii) A substance, the presence of which is essential for the combustion of another substance
   (iii) A substance that is burnt with a view to obtaining heat (and light)
2. Define ignition temperature of a substance.
3. Why does a paper cup containing water not burn when placed over a flame?
4. Define calorific value of a fuel.
5. Arrange bituminous coal, lignite, peat and anthracite in order of increasing age.
6. What is coal gas?
7. Name the process by which coke is obtained from coal.
8. Arrange petrol, diesel and kerosene in order of increasing boiling range.
9. A family slept on a winter night in a closed room after burning coal for warming the room. In the morning, nobody was found alive. Can you guess the possible cause of the mishap?
10. Name the compounds formed when haemoglobin reacts with oxygen and carbon monoxide respectively.

Long-Answer Questions

1. Describe a fixed-dome biogas plant.
2. How was coal formed?
3. How is petroleum formed?
4. Describe the principle of fractional distillation.
5. Draw a diagram to show the fractional distillation of petroleum.
6. Describe a candle flame.

Objective Questions

Choose the correct option.

1. Water is used to extinguish fire because it
   (a) raises the ignition temperature of the burning substance
   (b) lowers the ignition temperature of the burning substance
   (c) cools the burning substance to a temperature below its ignition temperature
   (d) conducts heat
2. Which among the following fuels has the highest calorific value?
   (a) Wood (b) Kerosene
   (c) LPG (d) Hydrogen

3. Which of the following is not derived from a fossil fuel?
   (a) LPG (b) Kerosene
   (c) Diesel (d) Biogas
4. Producer gas is a mixture of
   (a) CO and H_2 (b) CO and H_2O
   (c) CO and N_2 (d) CO_2 and H_2O

Fill in the blanks.

1. A log of wood attains the ignition temperature _______ than wood shavings do. (faster/more slowly)
2. In the liquid state, hydrogen is used as a fuel in _______ . (aircraft/spacecraft).
3. Insert the remark good, better, best or unsuitable for the fuels mentioned in the following table.

Fuel	Calorific value (kJ/g)	Ignition temperature (°C)	Remark
A	100	5	
B	80	70	
C	70	80	
D	60	90	

4. A good fuel burns _______ too fast _______ too slowly. (either/or/neither/nor)
5. Hydrocarbons are _______ compounds that contain only carbon and _______ . (organic/inorganic/hydrogen/elements of water)
6. The spent slurry of a biogas plant is _______ in nitrogen. (rich/poor)
7. Complete the following chemical equations and balance them.
   (i) $CH_4 + \_\_\_\_\_\_ \xrightarrow{\text{burn}} CO_2 + \_\_\_\_\_\_$
   (ii) $C_4H_{10} + \_\_\_\_\_\_ \xrightarrow{\text{burn}} CO_2 + \_\_\_\_\_\_$
   (iii) $Na_2CO_3 + \_\_\_\_\_\_ \longrightarrow Na_2SO_4 + \_\_\_\_\_\_ + H_2O$
   (iv) $NaHCO_3 + \_\_\_\_\_\_ \longrightarrow Na_2SO_4 + CO_2 + \_\_\_\_\_\_$

Match the columns.

1. Match the formulae given in column A with the descriptions in column B.

A	B
(a) CH_4	(i) A solid hydrocarbon
(b) C_4H_{10}	(ii) A liquid hydrocarbon
(c) $C_{10}H_{22}$	(iii) Natural gas
(d) $C_{18}H_{38}$	(iv) LPG

2. Match the fuels mentioned in column A with the descriptions given in column B.

A	B
(a) Biogas	(i) Fractional distillation of the residue obtained in petroleum refining
(b) Natural gas	(ii) Anaerobic fermentation of cattle dung
(c) Petroleum gas	(iii) Accumulated in petroleum wells
(d) Kerosene	(iv) Lowest-boiling fraction in petroleum refining
(e) Paraffin wax	(v) A liquid fraction from refining of petroleum

Indicate which of the following statements are true and which are false.

1. Coke is used in the production of water gas.
2. Asphalt is a fuel.

3. What burns in a candle is a hydrocarbon.
4. Combustion of hydrocarbons produces no greenhouse effect.
5. Some nitrogen dioxide and sulphur dioxide is also formed when a fossil fuel is burnt.

Writing with Fire

As you know, oxygen is needed for burning. It is ordinarily provided by air, but it can also be provided by a compound like potassium nitrate (KNO_3) or potassium chlorate ($KClO_3$). When mixed with a combustible substance, such a compound provides the combustible substance with the oxygen required for burning. You can understand this by performing the following activity.

Dissolve some crystals of potassium nitrate in a very small volume of water, say 2–3 mL. If the solid dissolves, add some more till no further solid dissolves. Write something with this solution on a piece of paper in such a way that the letters are in continuity. Allow the writing to dry up. Take a glowing (not inflamed) splinter and keep the glowing tip at one end of what you have written. You will find that what you have written starts burning with a red glow, which will move from one end to the other.

You can mix a drop of ink with the potassium nitrate solution to see what you are writing.

Now you can easily guess why potassium nitrate is used in gunpowder—a well-known explosive.

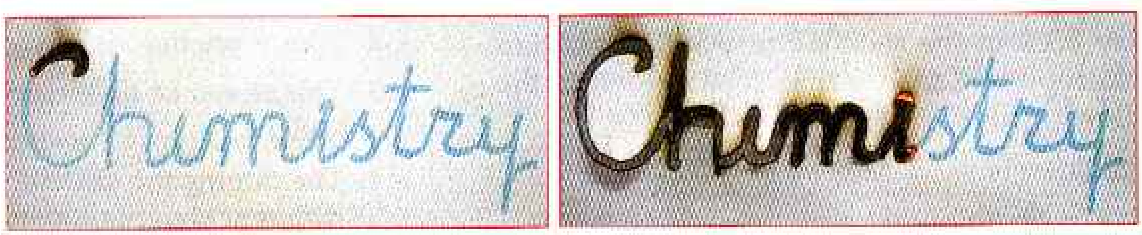

Fig. 3.12 What you have written with potassium nitrate solution burns with a glow.

The Role of Explosives in the Nobel Prize

To begin with, gunpowder was used as ammunition. But, later, it was used for other purposes as well. Since rocks are difficult to cut, they are blasted out using explosives containing gunpowder for making roads in mountains or extracting rocky minerals from a mine.

It was understood that a combination of a combustible substance and an oxygen-provider would make a good explosive. In 1846, an Italian chemist, Ascanio Sobrero, prepared a liquid, called nitroglycerine, by treating glycerine with nitric acid. He found that a sample of nitroglycerine explodes even when jerked a little. Many people died while experimenting with nitroglycerine.

In 1866, a Swedish engineer, Alfred Nobel, 'tamed' nitroglycerine by soaking it in a kind of porous earth called *kieselguhr*. He found that the product was easy to handle and exploded only when detonated, i.e., caused to explode by another small explosion, fire or electric spark. Nobel called the product dynamite and got it patented. Ten years later, he soaked nitroglycerine in gelatine and produced pellets and sticks of dynamite. He got this product patented too.

Depressed by the power of dynamite to cause devastation in warfare, Alfred Nobel wished to make amends. With the wealth he had earned from his invention, he instituted the Nobel Prize.

❑