Combustion and Flame

Essential Conditions Required for Combustion

When a burning matchstick is brought near kerosene gas stove (with its knob turned on), it will be observed that the gas coming out of the stove (i.e., LPG) starts burning instantly to produce heat and light. Hence, LPG is a fuel.

Similarly, there are fuels such as wood, coal, charcoal, petrol, diesel, etc. that are used for various purposes at home, in industry, and for running vehicles. These fuels burn to produce large amounts of heat. **Thus, burning or combustion is a chemical process in which substances react with oxygen to produce heat (and sometimes light).**

Do you know that there are some substances which do not burn in air?

Glass, stone, and iron nail are examples of non-combustible substances. The substances which do not burn in air are called **non-combustible substances.**

On the other hand, the substances that undergo combustion are said to be **combustible substances** or **fuels**. Fuels may be solid, liquid, or gaseous. The light that is produced during their combustion may either be in the form of a flame or glow.

Now, we know that substances can be classified as combustible or non-combustible. **However, if a combustible substance is exposed to air, then will it start burning on its own or does a fuel require special conditions for combustion to take place?**

In our houses, there are many substances that are made of wood. Even though they are exposed to air all the time, they do not burn on their own. However, when brought in contact with a burning matchstick or candle, they start burning. This shows that some conditions are required to be fulfilled before a substance starts burning.

Let us now discuss the essential requirements for combustion. The essential conditions for combustion to take place include the presence of a fuel, air, and heat.

We have learnt that heat is one of the necessary requirements for combustion to take place. However, does a fuel start burning as soon as it is exposed to a source of heat?

To observe this, try burning a candle by using a gas lighter. A gas lighter provides enough heat to initiate the combustion of LPG, but not enough heat to burn a candle, paper, or wood.

You must have heard that during extreme heat in summers, dry forests catch fire and very soon the fire spreads throughout the whole area. However, forests do not burn in winters when the temperatures are low. All these examples show that different substances catch fire at different temperatures.

Therefore, we can conclude that some minimum amount of heat is required for a substance to start burning. **The lowest temperature at which a substance burns is called its ignition temperature.**

Phosphorus is a very reactive substance having an ignition temperature of 35°C. Therefore, when it is exposed to air, it starts burning as this temperature is easily attained at room temperature. Therefore, it is stored in water to cut off its contact with air.

Matchsticks contain a mixture of antimony trisulphide and potassium chloride. The rubbing surface consists of powdered glass and red phosphorus. When a matchstick is struck against a rough surface, the red phosphorus gets converted into white phosphorus, and reacts with potassium chlorate. The heat produced in this reaction ignites anitmony trisulphide, thus triggering combustion.

Thus, a combustible substance cannot catch fire as long as its temperature is lower than its ignition temperature. This can be demonstrated by performing a simple activity as shown in the following animation.

Do you know that there are some substances which have very low ignition temperatures?

The substances which have very low ignition temperature are called **inflammable substances**. These substances catch fire very easily. LPG, petrol, and alcohol are some examples of inflammable substances. Hence, one should be very careful when using these substances.

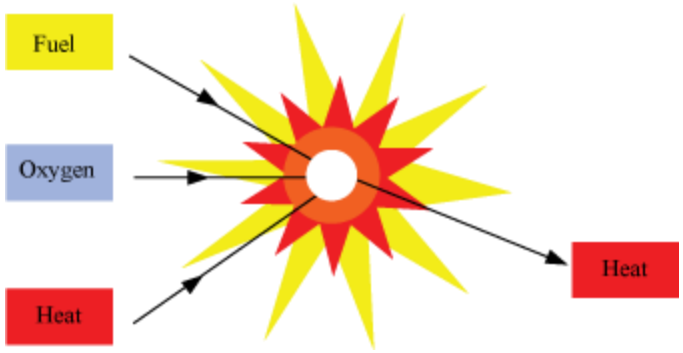
Supporter of combustion

The gaseous environment that supports combustion of a combustible substance is called supporter of combustion. The oxygen present in air is the main supporter of combustion.

Following is the summary of the factors on which rate of combustion depends:

- Size of combustible particles: Smaller the size of combustible particles, faster is the rate of combustion.

- Nature of combustible substance: Inflammable substances burn faster as compared to substances such as wood.
- Nature of gaseous environment
- Ignition temperature of combustible substances



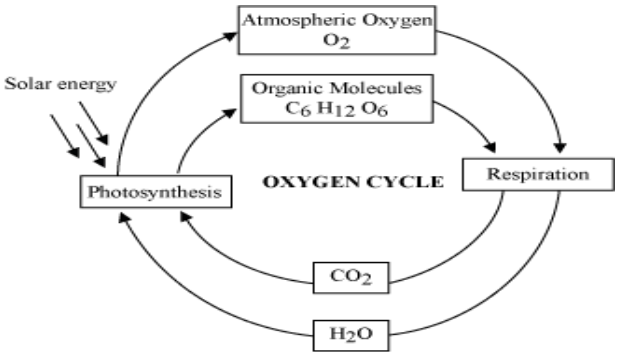
Do you know what happens if you pour water over fire?

The fire dies. This is because of the fact that air is necessary for combustion and when water is poured over the flame, air supply is cut off by the water vapours. Water also lowers the ignition temperature of the burning material below its ignition temperature.

Do you know?

Incomplete combustion occurs when there is not enough oxygen to allow the fuel to burn completely. A lot of smoke and other harmful substances are formed during incomplete combustion.

Oxygen is an important component of everyday life. We cannot survive without oxygen. It comprises about 21% of atmospheric air. It is a component of several biological molecules such as carbohydrates, proteins, nucleic acids and fats. Like carbon dioxide, **oxygen too is cycled through the process of photosynthesis and respiration**. It is also utilised during combustion or burning.



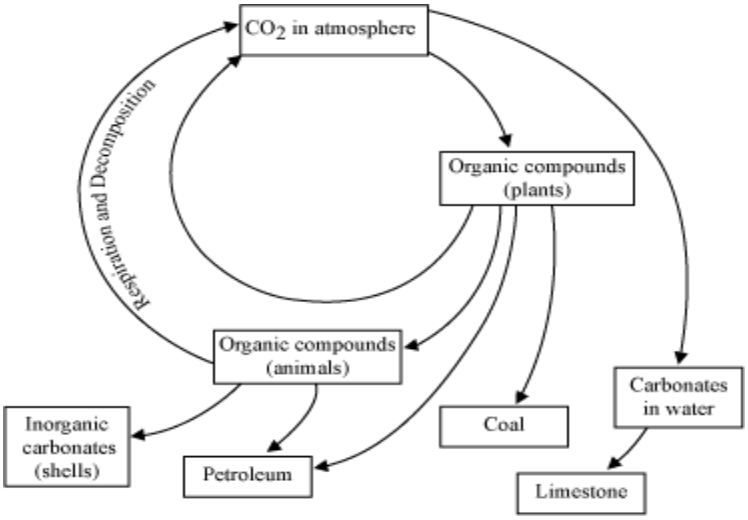
During photosynthesis, carbon dioxide and water combine to produce glucose and oxygen.This changes the atmospheric carbon into glucose molecules.

Glucose, which is a source of food, is utilised by organisms to produce energy during **respiration**. **During this process, glucose is broken down in the presence of oxygen to produce carbon dioxide and energy.**

Thus, through the processes of photosynthesis and respiration, carbon is utilised and then returned to the environment.

All organisms do not need oxygen to break down glucose and produce energy.

Combustion is another process that releases carbon dioxide. Many substances release carbon dioxide on burning. Carbon dioxide is a part of vehicular emissions and industrial fumes.



Comparison between Respiration and Burning

The following are the similarities between the two processes.

1. Both the processes utilise oxygen and liberate carbon dioxide.
2. Both the processes are exothermic in nature i.e., both the processes release energy.

The difference in the two processes is the amount of energy released during the reactions. During burning, energy is released at a much faster rate than during respiration. Also, the rate of liberation of energy can be easily controlled for respiration. Respiration occurs inside living cells, while burning occurs outside living cells. During the process of respiration, enzymes are required and energy is trapped in ATP molecules. On the other hand, enzymes are not required and ATP molecules are not formed during the process of burning.

Do you know what happens to the mass of a substance on burning?

When magnesium is burnt in air, a white-coloured metallic oxide is formed. Now, if 3 g of magnesium is taken, then 5 g of magnesium oxide is produced. Thus, there is an increase in mass by 2 g. The increase in mass is because of the mass of oxygen that combines with magnesium to form magnesium oxide.

$$2\,Mg + O_2 \rightarrow 2\,MgO$$

Thus, substances gain mass on burning.

Methods Used to Control Fire

The three things required for combustion to take place are:

1. Presence of a fuel,

2. Presence of oxygen, and

3. Attainment of ignition temperature of the fuel.

If the temperature of the fuel is below its ignition temperature, it will not burn. Therefore, fire can be extinguished by removing any one or all of these essential requirements. However, in most cases, it is not possible to remove the fuel. For example, if a house or car catches fire, then the whole thing acts like a big fuel. Thus, most fires are extinguished by bringing down the temperature of the fuel, or by controlling the oxygen supply available to the fuel, or by doing both.

You know that when the clothes of a person catch fire, he is either covered with a blanket, or pressed against the wall or ground. **Do you know why?** These actions prevent the contact of oxygen with clothes and help in extinguishing the fire.

You must have observed that whenever a building or house catches fire, the fire brigade is called upon for help. They pour large quantities of water on the fire to douse it. Water is the most common fire extinguisher. **Do you know how water helps in extinguishing fire?**

When water is poured, combustible substances which are on fire get cooled down, and their temperature decreases. When their temperature becomes less than their ignition temperature, they stop burning. This prevents the fire from spreading. Water vapours formed also cover the combustible material, which cuts off the contact between the fuel and oxygen. This also helps in extinguishing the fire.

If any building in your area catches fire, the first thing you ought to do is to call the fire service. The number to reach the fire service is **101.**

In spite of being the most common fire extinguisher, water is not used to extinguish fires involving oil, petrol etc. **Do you know why?**

Water is heavier than oil or petrol, which makes it sink below oil. Hence, oil keeps burning on top. Also, water is not a suitable fire extinguisher if the cause of fire is due to some electrical reasons. This is because water can conduct electricity. Thus, it can harm those trying to douse the fire.

Then, the question is that how can these fires be extinguished? These fires can be extinguished by cutting the supply of oxygen. This is done by using carbon dioxide, which is stored at a high pressure, as a liquid in cylinders (just how LPG is stored). These cylinders are commonly known as **fire extinguishers**.

CO_2 has an added advantage; it does not conduct electricity and can be effectively used to extinguish fires caused due to electrical reasons. Let us see a type of extinguisher to better understand it:

Soda-acid fire extinguisher: In this, sodium bicarbonate and sulphuric acid are filled in separate chambers. The sulphuric acid is kept inside a sealed bottle and hanged inside the cylinder. When the knob is opened, the sulphuric acid falls on sodium bicarbonate and reacts with it to produce carbon dioxide. CO_2 spreads over the fire and cuts the supply of oxygen to it.

Sand can also be used to extinguish fire involving electrical appliances, as it does not conduct electricity.

Do You Know:

Baking soda (chemically known as sodium bicarbonate) can also be used as a fire extinguisher. It releases carbon dioxide (CO_2) when heated.

Types of Combustion

Do you know that there are some substances, which spontaneously burn at room temperature, even when no heat is supplied to them?

For example, phosphorous, when kept in the presence of air, spontaneously bursts into flames at room temperature, even when no external heat is provided to it. On the other hand, substances like paper and wood do not burn on their own easily. However, these substances burn readily when they are taken near a burning candle or matchstick. Thus, depending on the nature of a substance, the way in which it burns is of different types.

There are three different types of combustion:

1. Spontaneous combustion
2. Rapid combustion
3. Explosion

We will now discuss each type of combustion individually.

Spontaneous combustion

The combustion in which substances suddenly burst into flames, without the application of any apparent cause is called **spontaneous combustion**. For example, sodium and phosphorus burn spontaneously in air, even when no external heat is provided to them.

Do You Know:

Sodium is a very reactive metal. It reacts spontaneously with oxygen and water at room temperature, to produce heat and light. Hence, it is stored in kerosene or in an inert atmosphere to cut off its contact with air and water.

Rapid combustion

The combustion in which substances burn rapidly to produce heat and light is called **rapid combustion**. In rapid combustion, external heat must be supplied so that the substances can burn.

For example, when a burning matchstick is brought near a gas stove (with its knob turned on), LPG burns rapidly to produce heat and light.

Do You Know:

Forest fires can be of two types: spontaneous or rapid.

Sometimes, forests catch fire spontaneously due to the heat of the sun or due to the strike of lightening. This is an example of spontaneous combustion.

However, most of the times forest fires result from the carelessness of human activities. People who go for picnics or safaris in jungles often forget to put out their campfire completely before leaving. This often results in forest fires. This is an example of rapid combustion.

Explosion

The combustion in which sudden reactions take place on ignition of some substances to produce heat, light, and sound is called **explosion**. For example, fireworks on ignition produce heat, light, and sound. Other substances such as dynamite also explode when ignited to produce huge amounts of energy. Dynamite is used to explode mountains to build roads, train tracks, and tunnels in hilly areas.

Crackers can also explode when subjected to high pressure. Therefore, one should be extremely careful while using them.

Different Parts Of A Flame

When a burning matchstick is brought near a gas stove, LPG gas burns rapidly with a flame. Similarly, magnesium burns to produce a white dazzling flame. **Do you know that not all substances produce a flame on burning?**

Only those substances, which vapourise during burning, produce flames. For example, when a candle burns, molten wax rises through the wick, and gets vapourised to form flames. On the other hand, charcoal does not vapourise on burning. Hence, it does not produce a flame. The flames of kerosene lamp, candle, and Bunsen burner are shown in the figure below.

Flames of kerosene lamp, candle, and bunsen burner

Can you observe the difference between the flames of a candle and Bunsen burner?

It will be noticed that the flame from the Bunsen burner is blue in colour while that of the candle is primarily yellow in colour.

Do you know the significance of these colours in the flame?

Each colour in a flame represents a different zone of the flame.The different zones present in a candle flame are as follows.

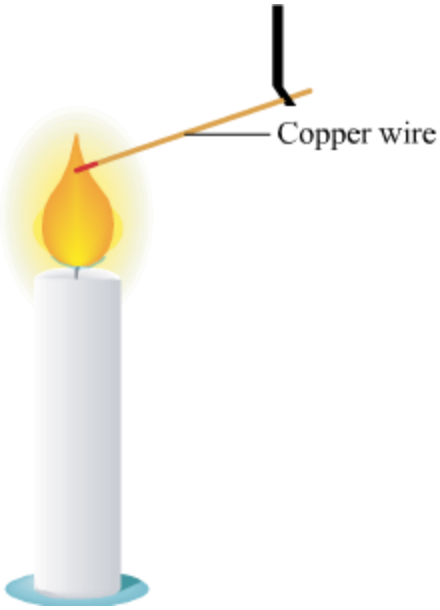
1. Innermost zone

2. Middle zone or the luminous zone

3. Outer zone or the non-luminous zone

Let us now discuss the properties of the three zones of a candle flame in detail. Let us watch the following animation.

The outermost zone of the flame is the hottest part of the flame and the innermost zone is the least hot part. If we hold a part of a thin long copper wire inside the non-luminous zone of the flame for 30 seconds, then that part of the copper wire becomes red hot (as shown in the figure below).

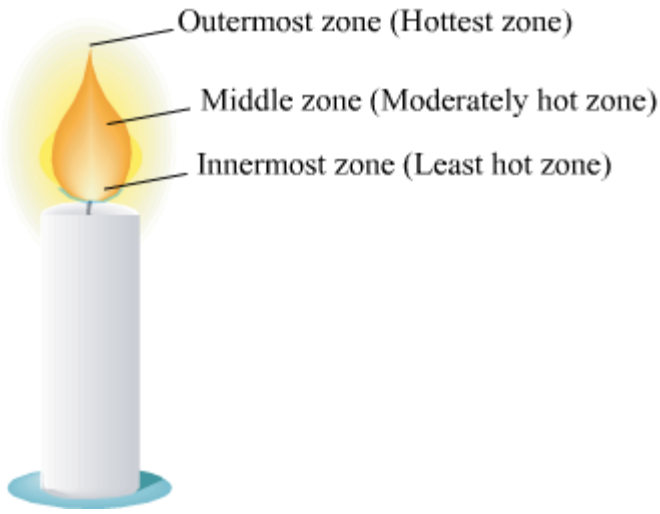


The outermost zone is the hottest part of the flame. Hence, to make gold and silver jewellery, goldsmiths use the outermost zone of the flame to melt gold and silver metal.

The given table summarizes the characteristics of the three zones present in a candle.

Different zones of a candle	**Innermost zone**	**Middle zone**	**Outermost zone**
Temperature	Minimum	Moderate	Maximum
Combustion	Zone of unburnt carbon particles	Zone of partial combustion	Zone of complete combustion

The given figure summarizes the characteristics of the three zones present in a candle:



Characteristics of a Good Fuel

Wood, charcoal, coal, kerosene etc. when undergo combustion, produce large amounts of heat. Substances that are burnt to produce heat are called **fuels**. These fuels are used for various purposes at home, in industries, and for running automobiles. However, not all fuels can be categorised as good fuels.

Do you know what the characteristics of a good fuel are?

A good fuel produces large amounts of energy and does not leave behind any undesirable substances. Also, it is cheap and is readily available.

Fuels may be solid, liquid, or gaseous. There is probably no fuel that can be considered as an ideal fuel. The given table lists some examples of different types of fuels.

Solid fuel	**Liquid fuel**	**Gaseous fuel**
Coal	Petrol	Natural gas
Wood	Diesel	Hydrogen gas
Charcoal	Kerosene	Petroleum gas

However, all these fuels do not produce the same amount of energy when burnt, which means that all fuels are not equally efficient.

Do you know how the efficiency of a fuel can be measured?

Fuel efficiency is measured in terms of its calorific value.

Calorific value of a fuel: It is the amount of heat energy produced on complete combustion of 1 kg of fuel. The unit of calorific value of fuel is **kilojoule per kilogram (kJ/kg)**

The calorific values of different fuels are listed in the given table in order of their decreasing values.

Fuel	**Calorific value (kJ/kg)**
Hydrogen	1,50,000
LPG	55,000
CNG	50,000
Methane	50,000
Kerosene	45,000
Diesel	45,000
Petrol	45,000
Biogas	35,000-40,000
Coal	25,000-33,000
Wood	17,000-22,000
Cow dung cake	6,000-8,000

It can be easily observed from the given table that hydrogen has the highest calorific value (1,50,000 kJ/kg). Hence, combustion of hydrogen produces a huge amount of heat energy. Therefore, it is considered as the best fuel. However, its transport and handling is difficult as its ignition temperature is very less, and it explodes when ignited.

Do You Know:

CNG is made by compressing natural gas, which is mainly composed of methane. The calorific value of CNG is about 50, 000 kJ/kg. Thus, it produces a huge amount of heat on combustion. It is considered as an environment friendly and clean fuel as it does not leave behind any harmful substances in the environment on burning. Hence, CNG is considered as a good fuel and is a substitute for petrol and diesel.

Harmful Effects Of Combustion Of Fuels

When fuels are burnt, many substances are obtained as products along with heat and light. Some of these substances are very harmful for the environment. For example, combustion of fuels produces large amounts of carbon dioxide, which causes global warming (an increase in the average temperature of the atmosphere of the Earth is called global warming).

Do You Know:

Global warming has resulted in the melting of glaciers in the polar region. This in turn has lead to an increase in the sea level, causing floods in coastal areas. Due to global warming, low lying coastal areas are in danger of getting permanently submerged under water.

Do you know why we are advised against sleeping in a closed room with burning coal or fire?

This is because air supply is limited in a closed room. When coal burns in a limited supply of oxygen, carbon monoxide instead of carbon dioxide is produced. Carbon monoxide is a very poisonous gas and can even cause death, if inhaled in large quantities.

Carbon monoxide lowers the binding affinity of haemoglobin in blood with oxygen. Hence, sufficient oxygen cannot be provided to various organs of the body, including the brain. Therefore, a person exposed to carbon monoxide may become unconscious and suffer from brain damage, or even death.

Other harmful effects due to burning of fuels are as follows:

1. When some fuels such as diesel, coal, and petrol are burnt, they release sulphur dioxide and oxides of nitrogen into the atmosphere. These oxides of sulphur and nitrogen dissolve in rain water to produce sulphuric and nitric acid respectively. Rains containing these acids become highly acidic in nature and are known as **acid rains**. Acid rains can cause large-scale damage to plants, soil, and buildings.

   Acid rain can corrode buildings made of marble and stone. It can contaminate water resources such as lakes and streams. This may even lead to the death of aquatic animals.

2. Fuels such as wood, coal, charcoal, etc. produce a lot of smoke in the atmosphere, which contain unburnt carbon particles. These fine particles are dangerous pollutants that can cause many respiratory diseases such as asthma.

   Do You Know:

   CNG is made by compressing natural gas, which is mainly composed of methane. When burnt, it releases much lesser carbon dioxide than coal, petrol and diesel. It is considered as

a clean fuel as it does not release pollutants into the atmosphere. Hence, CNG is considered an environment friendly fuel and is an excellent substitute for petrol and diesel.