COMBUSTION & FLAME

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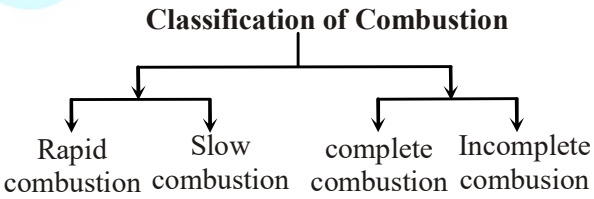
COMBUSTION

Introduction

Combustion is simply burning of a substance. **It is an exothermic process,** i. e., heat is produced on combustion. During combustion, carbon present in the fuel combines with oxygen and forms carbon dioxide while hydrogen forms water vapour. Therefore, the main products of combustion are CO_2 and water vapour. Now the combustion may be defined as **the burning of a substance in oxygen or air to produce heat and light.**

The process in which a substance combines chemically with oxygen or any other supporter of combustion, with simultaneous evolution of heat and light is called combustion.

CLASSIFICATION OF COMBUSTION



Rapid Combustion (or Burning)

The process in which a sustance combines chemically with oxygen at a temperature above its ignition temperature with the evolution of large amounts of heat and light in a short time is called rapid combustion, or burning. Burning of hydrocarbon fuels e.g., LPG, kerosene, petrol etc., is rapid combustion.

Combustion (or burning) of some common substances are described below:

- **Combustion of carbon :** Carbon (or charcoal) burns in air or oxygen to give CO_2 producing heat and light.

  Carbon (or charcoal) + Oxygen (from air) $\longrightarrow$ Carbon dioxide + Heat + Light

- **Combustion of hydrocarbons :** Hydrocarbons burn to produce carbon dioxide (CO_2), water (H_2O) and heat and light.

  For example, burning of methane or natural gas is described by the equation.

  Methane + Oxygen (limited amount) $\xrightarrow{\text{combustion}}$ Carbon dioxide + Water + Heat + Light

  Burning of LPG (which contains mainly butane) produces carbon dioxide, water, heat and light.

- **Combustion of magnesium :** Magnesium burns in air (or oxygen) to give magnesium oxide (MgO) producing heat and light.

  Magnesium + Oxygen (from air) $\xrightarrow{\text{combustion}}$ Magnesium oxide + Heat + Light

◈ Slow Combustion

A combustion reaction in which no light is produced and temperature of the substance remains almost uncharnged is called slow or spontaneous combustion.

Thus, a substance undergoes slow combustion without catching fire.

Some example of slow or spontaneous combustion are

(i) Digestion of food (or respiration)

(ii) Oxidation of yellow phosphorus at room temperature.

◈ Complete Combustion

The combustion in which the substance gets completely burnt to form the highest oxide of the substance is called complete combustion. Combustion in the presence of excess (or sufficient) oxygen or air is complete combustion.

For example, burning of carbon to carbon dioxide (CO_2) is complete combustion.

Carbon + Oxygen (from air) $\xrightarrow{\text{complete combustion}}$ Carbon dioxide

◈ Incomplete Combustion

The combustion reaction that takes place in the presence of insufficient quantity of oxygen (or air) is called incomplete combustion.

For example, when carbon is burnt in insufficient (limited) quantity of air, carbon monoxide is formed.

Carbon + Oxygen (from air) $\xrightarrow{\text{in complete combustion}}$ Carbon monoxide

➢ COMBUSTIBLE & NON-COMBUSTIBLE SUBSTANCES

The substances which burn readily are called combustible substances.

For example, Petrol, LPG (cooking gas), Wax, Kerosene, Paper, Cloth, Wood, Coal etc., are combustible substances.

The substances which do not burn are called non-combustible substances.

For example, Water, glass, sand etc., are non-combustible substances.

◈ Conditions Necessary for combustion :

- **Combustible Substance:** Combustible substances are the substances that can burn easily, e.g. wood, paper, cloth, petrol, kerosene, LPG, etc. Combustion of all carbon based fuels produces CO_2 and H_2O.
- **Supporter of Combustion :** We know that **oxygen** is necessary for combustion so it is called **supporter of combustion.** In most of the cases, oxygen is available from air. when a burning coal is covered with a vessel, the coal fire stops. Hence, it is clear that oxygen or air is necessary for burning.
- **Ignition Temperature :** The minimum temperature at which a substance catches fire and starts burning is known at its ignition temperature or ignition point or kindling temperature.

  SO, a substance must be heated to its ignition temperature so as to start burning.

Ex. The ignition temperature of a candle is low but it is higher than room temperature. So a candle does not start burning by itself at room temperature. When a burning matchstick is applied to the wick of candle, the heat produced by the matchstick raises the temperature of candle which is equal to its ignition temperature, so, the candle catches fire and starts burning. Different fuels have different ignition temperature.

➢ FUELS

A combustible substance which on burning produces a large amount of heat and light is called a fuel.

Coal, LPG , Petrol , Kerosene , wood etc.

◈ Classification of Fuels

Fuels are classified on the basis of physical sttes in which they occur. So fuels are classified as solid, liquid and gaseous fuels.

Classification of Fuels

Solid fuels Liquid fuels Gaseous fuels

- **Solid fuels :** Combustible substances which are solid at room temperature are called solid fuels. Solid fuels contain mainly carbon both as free and combined carbon. In rural areas, Firewood, Agricultural wastes, Animal-dung cakes are the major source of energy.

  Examples : Some solid fuels are :

  (a) Coal (b) Coke

  (c) Wood (d) Charcoal

  (e) Animal-dung cakes

  (f) Bagasse, Agricultural wastes
- **Liquid fuels :** Volatile liquids which produce combustible vapour are called liquid fuels. Kerosene is the most commonly used liquid fuel.

  Examples : Some common liquid fuels are :

  (a) Petrol (b) Diesel

  (c) Kerosene (d) Alcohol

  Petrol, diesel and kerosene are mixtures of hydrocarbons.
- **Gaseous fuels :** Combustible gases or mixtures of combustible gases are called gaseous fuels.

  Examples : Some commonly used gaseous fuels are :

  (a) Natural gas

  (b) Liquefield petroleum gas (LPG)

  (c) Biogas (or Gobar gas)

  (d) Coal gas

  (e) Water gas

  (f) Producer gas

  (g) Hydrogen gas

  (h) Compressed Natural (CNG)

  Petroleum gas is obtained as a by-product during the fractional distillation of petroleum.

◈ Characteristics of an ideal fuel

An ideal fuel should have the following characteristics :

- ◆ It should be fairly cheap and easily available.
- ◆ It should burn at moderate rate.
- ◆ It should not produce any poisonous and irritating fumes during burning.
- ◆ It should leave no residue (ash) after burning.
- ◆ It should produce large amount of heat per unit mass i.e., it should have high calorific value.
- ◆ It should be safe and convenient from the storage and tranportation point of views.
- ◆ Its ignition temperature should be above room temperature. So that it is safe to use such a fuel.

◈ Uses of Fuels

- ◆ **Cooking and Heating :** The most common use of fuels is for cooking and heating. The commonly used domestic fuels are wood, dry cattle dung, coal, charcoal, kerosene (in rural areas) and coal, kerosene, LPG (in urban areas).
- ◆ **For Transportation :** Fuels such as petrol, diesel and CNG are used for running cars, scooters, buses, trucks and trains. These automobiles are used for transportation from one place to another. The fuel used in aeroplanes is called **aviation fuel.**
- ◆ **For Generating Electricity :** Fuels such as coal and natural gas are used for generating electricity on a commercial scale, in Thermal power stations. Petrol, diesel and kerosene are also used for generating electricity in smaller generators commonly used at homes and shops, etc.
- ◆ **In Industry :** Fuels such as coal, natural gas, diesel and furnace oil are used in the industry for generating steam in boilers. Steam is required in industry for heating purposes and also for generating electricity for their own use in factory. Industry in the rural areas also uses biomass such as bagasse—the cellulose material left after extracting juice from the sugarcane for running boilers.
- ◆ **For Launching Space Vehicles :** Space vehicles are launched with the help of rockets. Rockets use special fuels called **propellants.** A propellant is a combination of a **fuel** and an oxidizer.

➢ FLAME

◈ Introduction

When you light a matchstick, it burns with a yellow flame. The flame produced by burning LPG is blue. The flame produced by kerosene when burnt in a lamp is yellow and smoky, but when burnt in a stove, the flame is blue and smoke-free. All gaseous combustible substances burn with a flame.

Liquid combustible fuels also burn with a flame. Solid combustible substances when burnt at low temperatue do not give a flame. At higher temperatures, however, when solid combustible materials vaporise, these also burn with a flame. Thus only those solid and liquid fuels which vaporise on heating burn with a flame.

For example, kerosene (a liquid fuel) and wax (a solid fuel) both vaporise on heating to burn with a flame. A flame is the shining zone in which a combustible gaseous material undergoes combustion producing heat and light.

The actual nature of the flame e.g., colour etc., depends upon the chemical nature of the combustible material. The shape of the flame depends upon the apparatus used for burning of the combustible material. But, when we talk of a flame and its structure, we generally refer to the candle or oil lamp (kerosene lamp) flame.

◈ Luminous and Nonluminous Flames

A blue-coloured flame which produces very little light is called nonluminous flame. A nonluminous flame is obtained when the fuel undergoes complete combustion a nonluminous flame is produced.

A fuel undergoes complete combustion only when the supply of air or oxygen is sufficient. Thus, when a fuel burns in the presence of sufficient air, a nonluminous flame is produced. LPG burns with a

nonluminous flame. Kerosene burns with a nonluminous flame in a pressure stove.

A yellow flame which produces heat and appreciable amount of light is called a luminous flame. A luminous flame is obtained when a fuel undergoes partial (or incomplete) combustion.

A fuel underoges incomplete/partial combustion only when the supply of air (or oxygen) is insufficient. So, when a fuel burns in the presence of limited (insufficient) air, a luminous flame is produced.

◈ Candel Flame

Candles are made from paraffin wax. Paraffin wax is obtained from the residue left during the fractional distillation of crude oil. Thus, paraffin wax is a petroleum product. It is a mixture of higher hydrocarbons and contains very high percentage of carbon. Paraffin wax is low melting and vaporises on heating.

A candle is a column of wax having an unspun cotton thread (called wick) at its centre all along its height. When a candle is lighted, the wax melts. This melted was rises up through the wick due to the capillary action and gets vaporixed. The vapour of wax then burns in the air to produce a luminous flame. A candle flame is shown alongside.

The candle flame is yellow and luminous due to incomplete combustion of wax vapour.

◈ Structure of a Candle Flame

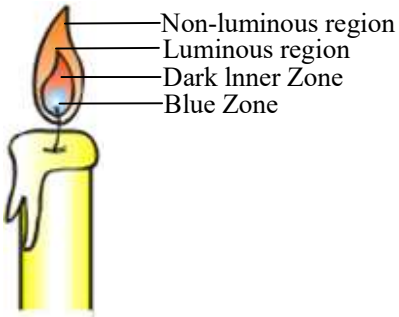
According to Berzelius (1822), a candle flame consists of four zones.

These are,

- Outermost nonluminous (blue) zone of complete combustion.
- Central (or middle) luminous zone of incomplete combustion.
- Inner dark zone of no combustion.
- Lowest blue zone.

These zones are described below :

1. **Outermost nonluminous zone of complete combustion :** This zone is faintly visible and surrounds the yellow luminous part of the flame. In this zone, the wax vapour undergoes complete combustion because plenty of air is present around it. This zone is the hottest part of the candle flame.
2. **Central (or middle) luminous zone of icomplete combustion :** The central luminous zone is the major part of the candle flame. This zone is bright yellow and luminous, and lies below the outermost nonluminous zone. In this zone, wax vapour undergoes incomplete combustion because not enough of air is present here. The incomplete combustion of wax vapour produces carbon particles. These unburnt carbon particles get heated up and start glowing. These glowing carbon particles make the flame luminous. Thus, the central zone of the candle flame is luminous due to the incomplete combustion temperature.
3. **Inner dark zone of no combustion :** The dark zone around the wick is called inner dark zone of no combustion. In this zone very little or no combustion takes place because in this zone no air is present. This zone is dark (black) due to the presence of unburnt carbon particles in the wax vapour. This part of the flame is the least hot.
4. **The lowest blue zone :** This zone is located at the base of the flame. The blue colour of this zone is due to the burning of the carbon monoxide produced in the dark zone.



Flame of a candle