

COMBUSTION & FLAME

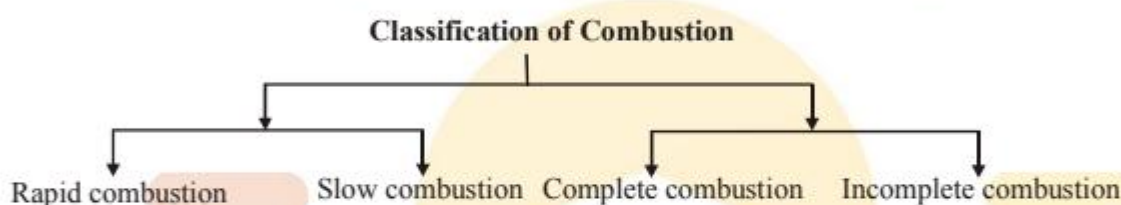
COMBUSTION

◆ 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

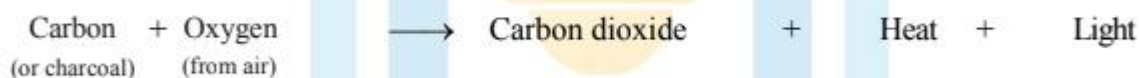


◆ Rapid Combustion (or Burning)

The process in which a substance 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.

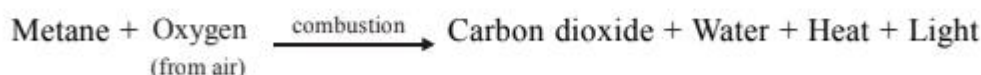
Combustion (or burning) of some common substances are described below :

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



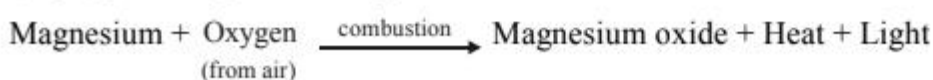
- ◆ **Combustion of hydrocarbons** : Hydrocarbons burn to produce carbon dioxide (CO_2), water (H_2O) and heat and light.

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



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.



◆ Slow Combustion

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

Thus, a substance undergoes slow combustion without catching fire.

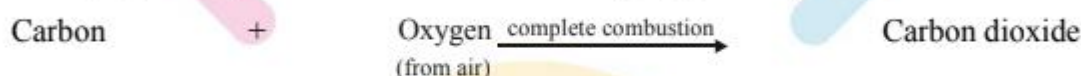
Some example of slow or spontaneous combustion are :

- (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.

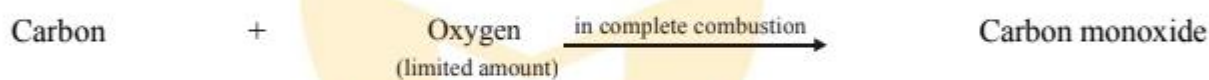
For example, burning of carbon to carbon dioxide (CO_2) is complete combustion.



◆ 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.



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

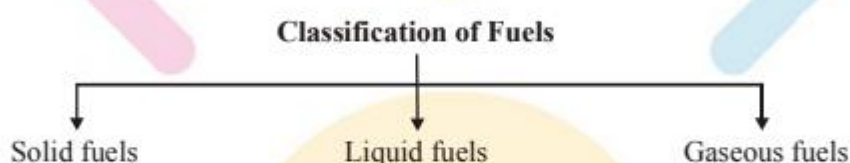
Ex. The ignition temperature of a candle is low but it is higher than room temperature. So a candle does not start burning by itself at room temperature. When a burning matchstick is applied to the wick of candle, the heat produced by the matchstick raises the temperature of candle which is equal to 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 states in which they occur. So fuels are classified as solid, liquid and 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) Liquefied 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 transportation 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 temperature 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 undergoes 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 wax rises up through the wick due to the capillary action and gets vaporised. 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.

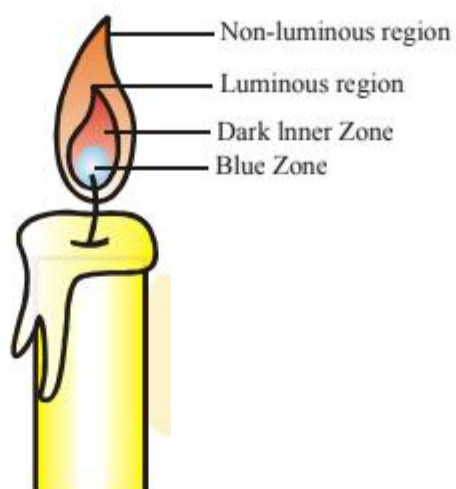
These are,

- ◆ 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 incomplete 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

EXERCISE - 1

VERY SHORT ANSWER TYPE QUESTIONS.

- Q.1 A circular blackish ring of unburnt particles are present in zone.
- Q.2 Define combustion.
- Q.3 Write a difference between burning of a candle and burning of coal.
- Q.4 What do you understand by combustible substances or fuels ?
- Q.5 Is burning of magnesium combustion ?
- Q.6 Give two examples of non-combustible substances.
- Q.7 What is essential for combustion ?
- Q.8 What do you mean by ignition temperature?
- Q.9 Does a matchstick burn by itself ?
- Q.10 What is the composition of the head of the matchstick ?
- Q.11 Which type of pollution occurs on burning wood ?
- Q.12 When a burning charcoal piece is covered with a glass jar then burning of the piece stops, why ?
- Q.13 Which will get fire first coal or kerosene ?
- Q.14 Which is the most common fire extinguisher?
- Q.15 Which poisonous gas is produced due to incomplete combustion of a fuel ?
- Q.16 Name the substance used to extinguish fire involving electrical equipments.

Short answer type questions

- Q.17 What are inflammable substances ?
- Q.18 What would you do when the clothes of a person catch fire ?
- Q.19 How is CO_2 able to control fire ?
- Q.20 What do you understand by Explosion ?
- Q.21 Which zone of a flame does a goldsmith use for melting gold and silver and why ?
- Q.22 How can water boil in a paper cup without burning it ?
- Q.23 What are the three zones of a flame ? Draw a labelled diagram of a candle flame.
- Q.24 Why does the matchstick start burning on rubbing it on the side of the matchbox ?
- Q.25 What are the essential requirements for producing fire ? On which principle the fire extinguisher works ?
- Q.26 Paper by itself catches fire easily whereas a piece of paper wrapped around an aluminium pipe does not.
- Q.27 Explain how water is able to control fires ?

- Q.28** Define –
(a) Spontaneous combustion.
(b) Rapid combustion.
- Q.29** (i) What is calorific value ? Write its unit.
(ii) In an experiment 4.5 kg of a fuel was completely burnt.
The heat produced was measured to be 180,000 kJ. Calculate the calorific value of the fuel.
- Q.30** Why is it difficult to burn a heap of green leaves but dry leaves catch fire easily ?
- Q.31** What do you understand by Global Warming? Give any two consequences of Global warming.

Long answer type questions

- Q.32** What are the characteristics of an ideal fuel?
- Q.33** Why is CO_2 an excellent fire extinguisher ? Draw a diagram of fire extinguisher.
- Q.34** What is acid rain. Write its harmful effects.
- Q.35** How will you show that for a substance to burn, it is essential to reach its ignition temperature ?

EXERCISE - 2

SINGLE CORRECT ANSWER TYPE QUESTIONS

- Q.1** Which of the following has the lowest ignition temperature ?
(A) petrol (B) kerosene
(C) coal (D) LPG
- Q.2** The substance having the highest calorific value is
(A) LPG (B) hydrogen
(C) oxygen (D) coal gas
- Q.3** The zone of the candle flame which is moderately hot is called,
(A) nonluminous zone
(B) luminous zone
(C) inner dark zone
(D) lowest blue zone
- Q.4** Which of the following has the highest calorific value ?
(A) wood (B) dung cake
(C) methane gas (D) biogas
- Q.5** Which of the following causes acid rain ?
(A) carbon dioxide
(B) sulphur trioxide
(C) carbon monoxide
(D) oxides of sulphur and nitrogen
- Q.6** Which of the following gives a pollution-free environment when burnt
(A) dung cakes (B) kerosene
(C) wood (D) biogas
- Q.7** Combustion takes place
(A) in the absence of oxygen
(B) in the presence of nitrogen
(C) in the presence of oxygen
(D) none of these
- Q.8** The percentage of oxygen, which supports combustion, in atmosphere is
(A) 60% (B) 21%
(C) 78% (D) 40%

- Q.9** Ignition temperature is the temperature at which a combustible substance
(A) boils (B) melts
(C) catches fire (D) none of these
- Q.10** Ignition temperature of phosphorus is
(A) 65°C (B) 35°C
(C) 100°C (D) 45°C
- Q.11** The coldest region of a candle flame is
(A) blue zone
(B) dark zone
(C) luminous zone
(D) non-luminous zone
- Q.12** The gases that contribute to green house effect are –
(A) Methane
(B) Carbon dioxide
(C) Nitrogen
(D) Both methane and carbon dioxide
- Q.13** Which of the following has the lowest ignition temperature ?
(A) CNG (B) Coal
(C) Gasoline (D) Hydrogen
- Q.14** In which of the following is not a necessary condition of combustion ?
(A) Presence of combustible substance
(B) Presence of a supporter of combustion
(C) Attainment of ignition temp. of the fuel
(D) Presence of carbon dioxide
- Q.15** A luminous flame appears
(A) red (B) green
(C) yellow (D) blue
- Q.16** The harmful effect of the usage of fossil fuels is
(A) Green house effect
(B) Depletion of ozone layer
(C) Acid rains
(D) All of these

ANSWER KEY

EXERCISE-1

VERY SHORT ANSWER TYPE QUESTIONS.

Sol.1 Luminous zone

Explanation : The blackish ring is due to the deposition of unburnt particles which are present in the luminous zone.

Sol.2 Combustion is a chemical process in which a substance reacts with oxygen of air to produce heat and light.

Sol.3 A candle burns with a flame while coal does not burn with a flame.

Sol.4 Those substances which burn or catch fire easily are called combustible substances or fuels e.g. wood, coal etc.

Sol.5 Yes, burning of magnesium is combustion as it produces heat and light.

Sol.6 Glass and Stone

Sol.7 Air or oxygen

Sol.8 The minimum temperature at which a substance catches fire and starts burning is called as ignition temperature.

Sol.9 No, a matchstick does not burn by itself because its temperature is lower than its ignition temperature.

Sol.10 The head of the matchstick contains antimony trisulphide and potassium chlorate.

Sol.11 Air pollution

Sol.12 It is due to the absence of oxygen (air) inside the jar. Oxygen is essential for burning.

Sol.13 Kerosene because its ignition temperature is lower than coal.

Sol.14 Water

Sol.15 Carbon monoxide gas.

Sol.16 Carbon dioxide (CO₂)

Short answer type questions

Sol.17 Those substances which have very low ignition temperature and can easily catch fire with a flame are known as inflammable substances. e.g. Petrol, LPG etc.

Sol.18 We will immediately cover the person with a blanket. It will prevent the entrance of air in the blanket. As a result, the fire will extinguish (air is necessary for burning).

Sol.19 CO₂ is heavier than oxygen. So it covers the fire like a blanket. Since the contact between the fuel and oxygen is cut off, the fire is controlled and CO₂ does not harm the electrical equipment.

- Sol.20** The combustion in which a sudden reaction takes place with the evolution of heat, light, sound and gas is known as explosion e.g. ignition of a cracker.
- Sol.21** A goldsmith uses outermost or non-luminous zone of a flame for melting gold and silver because this is the hottest part of the flame.
- Sol.22** When we heat water in a paper cup then the heat supplied to the paper cup is transferred to water by conduction and the temperature of water goes on rising till it starts boiling. So, in the presence of water, the temperature of paper is not reached to its ignition temperature and the paper cup does not burn.
- Sol.23** The three zones of a flame are dark zone, luminous zone and non-luminous zone.

Different zones of Candle flame



- Sol.24** The rubbing surface contains powdered glass and a little red phosphorus. The head of the matchstick contains antimony trisulphide and potassium chlorate. When the matchstick is struck against the rubbing surface then some red phosphorus gets converted into white phosphorus which readily reacts with potassium chlorate of the head of the matchstick to produce sufficient heat to ignite antimony trisulphide. Thus the matchstick starts burning.
- Sol.25** There are three essential requirements for producing fire. They are-
- Fuel
 - Air or oxygen
 - Heat (to raise the temperature of the fuel beyond the ignition temperature)
- The fire extinguisher removes one or more of the requirements which are needed for burning e.g. it prevents supply of air or to bring down the temperature of the fuel or both.
- Sol.26** When a piece of paper wrapped around an aluminium pipe is heated then the heat is transferred to the aluminium pipe because Al is a good conductor of heat. So the temperature of the paper does not reach its ignition temperature. But in case of heating the paper itself, the ignition temperature of the paper reaches readily and the paper catches fire.
- Sol.27** Water cools the combustible material so that its temperature is brought below its ignition temperature. This prevents the fire from spreading. Water vapours also surround the combustible material. So the supply of air is stopped and the fire is extinguished.

Sol.28 (a) Spontaneous combustion : The combustion in which a material suddenly bursts into flames without any visible cause is known as spontaneous combustion e.g. spontaneous fires of forests occur due to the heat of the sun or due to lightning strike.

(b) Rapid Combustion : The combustion in which a material burns rapidly and produces heat and light is called as Rapid combustion e.g. phosphorus burns in air readily at room temperature.

Sol.29 (i) **Calorific value** of a fuel is the amount of heat energy evolved on complete combustion of 1 kg of a fuel. Its unit is kilojoule per kg (kJ/kg).

(ii) The heat produced by burning 4.5 kg of a fuel = 180,000 kJ. The heat produced by burning 1 kg of a fuel = $180,000 \text{ kJ} / 4.5 \text{ kg} = 40,000 \text{ kJ/kg}$

So, the calorific value of the fuel = 40,000 kJ/kg

Sol.30 For the combustion, the substance must be heated to its ignition temperature. If the ignition temperature is not reached then the combustion does not start. Green leaves contain moisture which increases their ignition temperature. Hence it is difficult to burn a heap of green leaves. The ignition temperature of dry leaves is low. So, they catch fire easily.

Sol.31 **Global Warming** is the increase in temperature of the atmosphere of the Earth due to the increased concentration of gases like CO_2 .

Consequences of Global Warming

1. Global warming leads to the melting of glaciers. So the level of sea water will increase and floods will take place.

2. Higher global temperature may increase the infectious diseases like malaria, dengue, yellow fever etc.

Long answer type questions

Sol.32 The characteristics of an ideal fuel are –

- (i) It should be readily available and cheap.
- (ii) It should produce a large amount of heat (high calorific value)
- (iii) It should burn without giving any harmful gases.
- (iv) It should burn easily in air at a moderate rate (proper ignition temperature).
- (v) It should not leave behind any undesirable substances after burning.

Sol.33 CO_2 can be used as an extinguisher for fires involving electrical equipment and inflammable materials like petrol. It can be stored at high pressure as a liquid in cylinders. On releasing it from the cylinder, it expands enormously in volume and cools down. Thus, it not only forms a blanket around the fire but also brings down the temperature of the fuel. Hence, it is an excellent fire extinguisher.

Sol.34 When rain water dissolves oxides of sulphur and nitrogen (produced due to burning of coal, petrol etc in the atmosphere) then acids are formed. Such rain is known as acid rain. Acid rain contains mainly sulphuric acid and nitric acid.

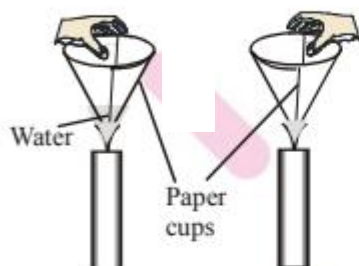
Harmful effects of acid rain

1. Acid rain damages leaves of trees, plants and retards the growth of certain crops like peas, beans etc.

2. It damages buildings and statues specially made of marbles and metals e.g. Taj Mahal at Agra is being affected by acid rain.

3. It is toxic to aquatic life.

Sol.35 We make two paper cups by folding a sheet of paper. Some water is poured in one of the cups. Then we heat both the cups separately with a candle. We will observe that the paper cup without water (empty) burns and the cup having water does not burn. This is because the ignition temperature of empty paper cup reaches quickly on heating and it burns. But in case of the cup with water, the heat supplied to the paper cup is transferred to water by conduction. So, in the presence of water, the ignition temperature of paper is not reached and it does not burn. Hence for a substance to burn, it is essential to reach its ignition temperature.



EXERCISE-2

Ques.	1	2	3	4	5	6	7	8	9	10
Ans.	D	B	A	D	D	D	C	B	C	B
Ques.	11	12	13	14	15	16				
Ans.	B	D	D	D	C	D				