UNIT 14

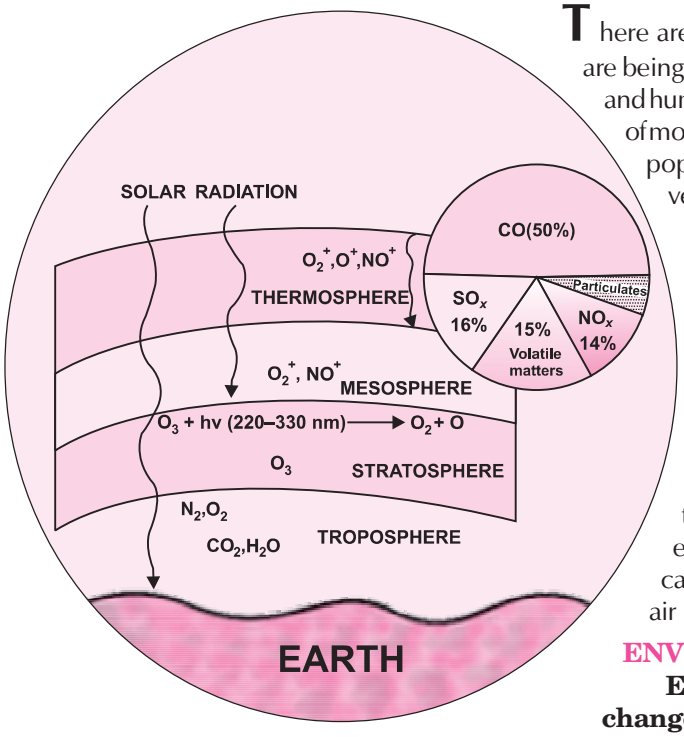
ENVIRONMENTAL POLLUTION

OBJECTIVES

Building on.....

Assessing.....

Preparing for Competition.....



There are a number of substances (toxic as well as non-toxic) which are being added to our surroundings or environment by natural events and human activities. These are in fact, the undesirable consequences of modern civilization, increased use of natural resources, increasing population, advancement in industries, increase in number of vehicles, etc. These substances which are continuously going into air, water and soil bring about undesirable changes in physical, chemical and biological characteristics of our environment and adversely affect the life processes of animals and plants.

The branch of science which deals with the chemical phenomena occurring in the environment is called **environmental science**.

This deals with the study of the origin, transport, reactions, effects and consequences of chemical species in the environment. The contamination of any part of the environment is called pollution and the substances which cause pollution are called pollutants. The pollutants can cause air pollution, water pollution or soil pollution.

ENVIRONMENTAL POLLUTION

Environmental pollution is the **effect of undesirable changes in our surroundings (air, water or land) that have harmful effects on human, animal and plant life as well as on materials.** Pollution may be natural or man made. It can be classified according to the components of environment being damaged. These are :

(*i*) Air pollution
(*ii*) Water pollution
(*iii*) Soil (land) pollution.

A substance which causes pollution is called **pollutant.** The pollutants can be solid, liquid or gaseous substances. These can be *degradable* like discarded vegetables and fruits which rapidly break down by natural

processes. The pollutants can also be *non-degradable* such as aluminium pieces, mercury, DDT etc. which remain in the environment in an unchanged form for many decades. In general,

pollutants are the substances made by us, used by us and even thrown by us as waste products which pollute the environment directly or indirectly in one way or other.

Do you know that an average human being needs about 12–15 times more air than the food. So, even a small amount of pollutants in the air become significant compared to similar levels present in the food.

Can you believe, man is the principal source of pollution ?

SOME COMMONLY USED TERMS

Some commonly used terms in environmental chemistry are :

1. Pollutant

***When the concentration of a substance already present in nature or of a new substance increases to undesirable proportions causing danger to human beings, other animals or vegetation and other materials, the substance is treated as a* pollutant.** The pollutants spoil the environment and are harmful to living organisms and other materials . The common pollutants are :

(*i*) gases like carbon monoxide, sulphur dioxide, oxides of nitrogen, etc.
(*ii*) compounds of metals like lead, mercury, zinc, cadmium, arsenic, etc.
(*iii*) pollen grains, dust
(*iv*) pesticides and detergents
(*v*) sewage and
(*vi*) radioactive substances.

It may be noted that normally highly toxic substances are considered as pollutants. However, the substances which are normally harmless can cause pollution if they are present in undesirable concentrations. For example, nitrate is added to soil as a fertilizer to increase growth of the plants, but an excessive concentration of nitrate present in drinking water can be harmful especially to young children.

2. Contaminant

***A substance which does not occur in nature but is introduced by human activity into the atmosphere affecting its composition* is called contaminant.** It may or may not be harmful to the living organisms or non-living components.

The contaminant is classified as pollutant when it has some harmful effect. For example, pyrosulphuric acid ($H_2S_2O_7$) leaked from a defective tank killed many persons and caused skin and breathing problems to many persons in Delhi. Since pyrosulphuric acid does not occur in the atmosphere, so it is a contaminant. But because of its dangerous effect, it is also regarded as a pollutant.

Generally, highly toxic substances are considered as pollutants.

3. Source

***The site from which the pollutants or contaminants come* is called source.** Every pollutant originates from a source. The source is particularly important because its knowledge helps to develop the methods to eliminate pollutants.

4. Sink

***The material or medium which consumes or interacts with a long lived pollutant* is called sink.** For example, a marble wall acts as a sink for atmospheric sulphuric acid because of the reaction :

$$CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + H_2O + CO_2$$

The oceans are sinks for atmospheric carbon dioxide and other water soluble gases.

Ground water and subsoil water also act as sinks for pesticides used in agriculture.

5. Receptor

***Anything that is affected by the pollutants* is called receptor.** For example, human beings are the receptor of photochemical smog causing irritation in eyes and breathing problems.

6. Speciation

Speciation means the identification of different chemical forms or species of an element or a compound present in the environment. For example, mercury may be present in the environment in various forms such as elemental mercury, mercury salts, organometallic mercury species; CH_3Hg^+, $(CH_3)_2Hg$. It is very essential to identify the chemical species of the pollutants because some species may be more toxic than others and need special care. For example, alkyl mercury derivatives [CH_3Hg^+,$(CH_3)_2$ Hg] are highly poisonous as compared to other species of mercury.

7. Threshold Limit Value (TLV)

This indicates the permissible limit of a pollutant toxic in atmosphere to which a healthy worker is exposed during 8 hours a day or 40 hours a week for life time without any adverse effects. TLVs are determined by experimentation on animals, medical knowledge and experience, epidemiology surveys and environmental studies.

For example, TLV of CO is 50 ppm and that of CO_2 is 5000 ppm. But TLV for a poisonous gas phosgene is only 0.1 ppm.

In an environment pollution process, a pollutant originates from a **source.** It is transported by air or water or is dumped on land by man. Some of the pollutants may be absorbed (assimilated) or chemically changed by the **sink.** The remaining pollutants build up to harmful concentrations and affect the **receptor.** This is shown in Fig. 1.

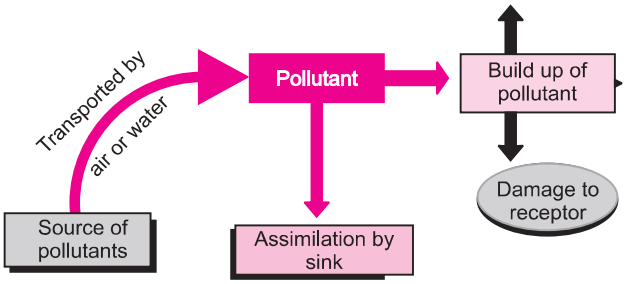


Fig. 1. A schematic representation of an environmental pollution process.

CHEMICAL REACTIONS IN ATMOSPHERE

The gaseous envelope surrounding the earth is known as **atmosphere.** The two major components of dry and clean air in the atmosphere (by volume) are nitrogen (78.09%) and oxygen (20.95%). Argon (0.934%) and carbon dioxide (0.034%) are the minor components of the atmosphere. Air can hold water vapour from 0.1 to 5% by volume and also contains trace of elements such as noble gases (neon, helium, krypton, xenon), hydrogen, methane, sulphur dioxide, ammonia, ozone, etc.

The atmosphere surrounding us may be divided into four regions :

(i) troposphere
(ii) stratosphere
(iii) mesosphere
(iv) thermosphere.

About 80% of the total mass of air and almost all of the water vapours of the atmosphere is found in the inner layer known as **troposphere** which extends to 8 to 12 km above the earth's surface. This is the most important region of the atmosphere because it is the domain of all living organisms including animals and plants. This has homogeneous composition of major gases (N_2, O_2, CO_2, water-vapour and noble gases). It has decreasing temperature with increasing altitude from the earth surface with a minimum around –56°C at the maximum height of the troposphere. However, on certain occasions, the temperature may increase to some extent with altitude instead of decreasing. Such a situation is called **temperature inversion** and is due to trapping of a layer of cold air by a warmer upper layer.

With increasing altitudes from the earth's surface, the other regions are *stratosphere* (11– 50 km), *mesosphere* (50 – 90 km) and *thermosphere* (90 – 500 km). The stratosphere contains nitrogen, oxygen and ozone.

In **stratosphere,** the temperature rises with increasing altitude showing a maximum of –2°C. This phenomenon is due to the presence of ozone which may absorb ultraviolet radiation and raises the temperature in this region. This act of ozone protects us from the harmful effects of sun's ultraviolet radiation. This region contains N_2, O_2, O_3 and O-atoms. Due to the presence of ozone layer, this layer is also called **ozonosphere.**

The region beyond stratosphere is dominated by positive ions such as O_2^+, O^+ and NO_2^+ in addition to N_2 and O_2 and is called **mesosphere.** This extends upto 90 km.

Above 90 km, the region is called **thermosphere** which contains ions such as O_2^+, O^+, NO^+ and free electrons.

The regions mesosphere and thermosphere are collectively called **ionosphere** because these contain ionized gases.

The different regions of the atmosphere are shown in Fig.2.

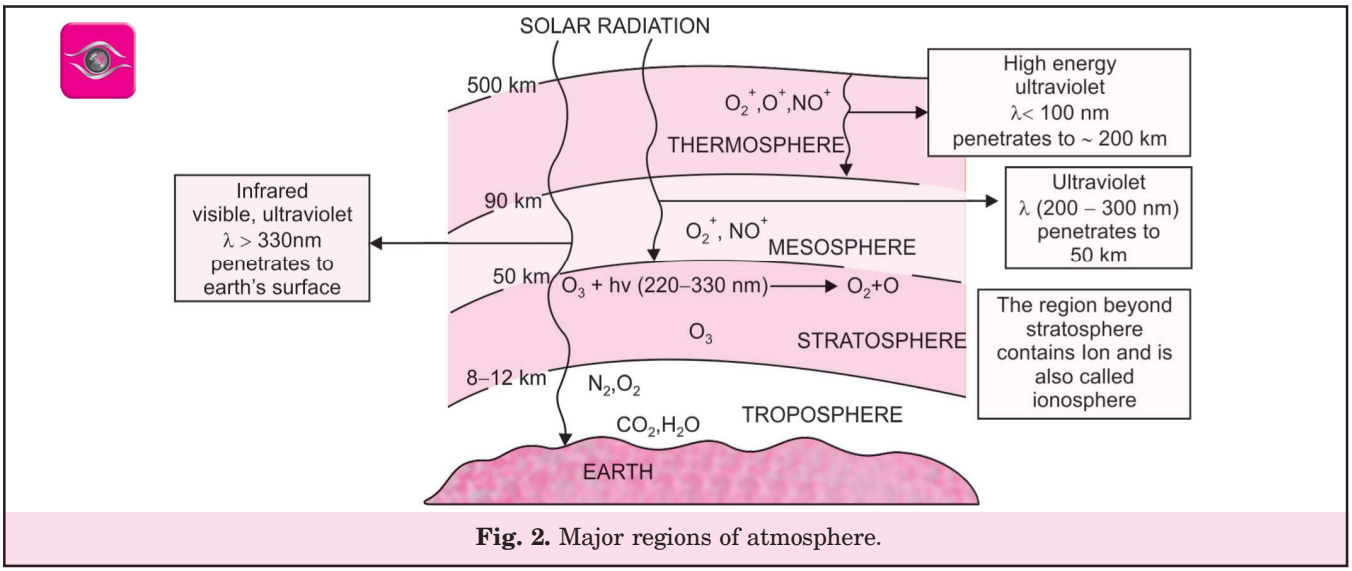


Fig. 2. Major regions of atmosphere.

TYPES OF ENVIRONMENTAL POLLUTION

The environmental pollution may be of the following types :

1. Atmospheric pollution

2. Water pollution

3. Soil or land pollution.

The atmospheric pollution is generally studied under two heads :

(*a*) Tropospheric pollution

(*b*) Stratospheric pollution.

Tropospheric pollution is much more widespread and we all are concerned about it. Since only a few substances produced by human activity reach the stratosphere, its pollution results in the depletion of ozone layer, which may result into very serious problems.

AIR POLLUTION

Air is never found clean due to natural and man-made pollution. Gases such as carbon monoxide, nitrogen oxides, sulphur oxides, hydrogen sulphide and many volatile organic compounds are continuously released into the atmosphere due to natural and human activities. **Air pollution *occurs when the concentration of a normal component of the air or a new chemical substance added or formed in air builds up to undesirable proportions causing harms to humans, other animals, vegetation and materials.***

The chemical substance causing pollution is called **air pollutant.** About 90% of air pollution problems are caused by the pollutants such as carbon monoxide, sulphur oxides, volatile organic compounds, nitrogen oxides and suspended particulate matter (such as carbon, dust, pollen, metal, etc.) as shown in Fig. 3.

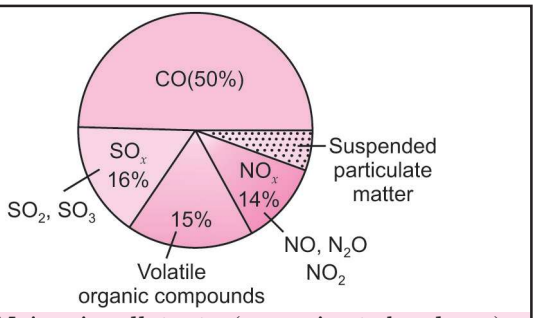


Fig. 3. Major air pollutants (approximate bundance).

Sources of Air Pollutants

The air pollution is caused by natural activity and human activity. The natural sources of air pollution are volcanic eruptions, forest fires (caused by lightning), pollen dispersal, evaporation of volatile organic compounds from leaves, bacterial decomposition of organic matter, wind erosion of soil and natural radioactivity.

The main human activities responsible for polluting the air are burning of fuels (coal, oil, gasoline, etc.) in power and industrial plants and in motor vehicles and industrial processes and industrial wastes.

Air Pollutants

There are two types of air pollutants :

1. *Primary air pollutants*

2. *Secondary air pollutants.*

1. Primary air pollutants

A primary air pollutant is a harmful chemical substance that directly enters the air as a result of natural events or human activities. The primary pollutants are :

(*i*) Carbon oxides (CO and CO_2)

(*ii*) Nitrogen oxides (NO)

(*iii*) Sulphur oxides (SO_2)

(*iv*) Hydrocarbons

(*v*) Suspended particulate matter.

2. Secondary air pollutants

A secondary air pollutant is a harmful chemical that forms in the air due to a chemical reaction between two or more air components or a primary pollutant and one or more air components. For example, sulphur dioxide is a primary pollutant in air. It reacts with oxygen gas in the atmosphere to form the secondary pollutant sulphur trioxide (SO_3).

$$\underset{\text{Primary pollutant}}{2SO_2} + O_2 \longrightarrow \underset{\text{Secondary pollutant}}{2SO_3}$$

Even, the sulphur trioxide formed may react with the water vapour in air to form sulphuric acid.

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

Sulphuric acid is, therefore, also a secondary pollutant.

The common secondary pollutants are :

SO_3, H_2SO_4, NO_2, N_2O, HNO_3, H_2O_2, O_3, nitrate and sulphate salts, etc.

Pollutants can also be classified as:

(*i*) Biodegradable pollutants and

(*ii*) Non-biodegradable pollutants

(*i*) **Biodegradable pollutants.** *These are the materials which are easily decomposed by the microorganisms either by the nature itself or by suitable treatment so that their degraded products donot cause any serious effects on the environment.* For example, domestic sewage, cow-dung etc.

(*ii*) **Non-biodegradable pollutants.** *These are the materials which donot undergo degradation or degrade slowly or partially and their presence even in very small amounts in the environment is very harmful for humans as well as plants life.* These pollutants not only accumulate in the environment but are often biologically magnified because they move in biochemical cycles and along food chains. For example, aluminium, mercury, D.D.T., plastic materials, many chemicals, nuclear wastes etc.

The main air pollutants and their major sources are given in Table 1.

Table 1. Some common air pollutants and their major sources.

Pollutant	Major pollutant source
CO	Transportation, autoexhaust, petroleum, paper industries, iron and steel industries, solid waste disposals.
CO_2*	Fuel combustion and industrial processes.
SO_2	Metallurgical operations, combustion of coal and oil, paper, manufacture of H_2SO_4.
NO, NO_2	Fertilizer industries, explosive industries, manufacture of HNO_3.
H_2S	Petroleum refining, coke ovens, natural gas plants.
Cl_2	Industrial processes such as paper, plastics, dyes, chlorinated hydrocarbons.
NH_3	Natural biological processes, industrial processes, ammonia works.
Hydrocarbons	Petroleum refineries, chemical processes, rubber manufacture, transportation, solid waste disposal.
Particulates	Volcanic eruptions, metallurgical operations such as smelting and mixing, incomplete combustion in industrial processes.

*Usually CO_2 is not considered as pollutant.

Other air pollutants are metals like Be, Ba, Cd, Fe, Mn, Pb, Hg, Ni, Zn (from mining and metallurgy), non-metals such as As, P, Se (from combustion of industrial fuels, fertilizers) radioactive substances (from nuclear power plants).

Industrial accidents can also play havoc for the environment. For example, an industrial accident occurred in the Union Carbide factory on December 3, 1984 in Bhopal. It released a large scale of poisonous MIC (methyl isocyanate) and caused excessive damage to all forms of life.

TROPOSPHERIC POLLUTION

The tropospheric pollution occurs because of the presence of undesirable solid or gaseous particles in air. The pollutants may be broadly classified into two major types :

1. Gaseous air pollutants. These include oxides of sulphur, nitrogen and carbon, hydrogen sulphide, hydrocarbons, ozone and other oxidants.

2. Particulate pollutants. These are dust, fumes, mist, spray, smoke, etc.

These are briefly discussed.

SOME COMMON AIR POLLUTANTS

Although there are many sources of air pollutants, the common pollutants come from combustion processes. Let us discuss the major air pollutants.

A. GASEOUS AIR POLLUTANTS

1. Oxides of Carbon

(*a*) Carbon monoxide (CO)

It is one of the most serious air pollutant. It is a colourless, odourless and tasteless gas above 81 K. It is heavier than air and is not soluble in water. It is one of the most serious air pollutants. It is highly poisonous to living beings because of its ability to block the delivery of oxygen to the organs and the tissues.

Sources of CO in air

The **main sources** of air pollution of CO are the automobile engines and defective furnaces. Some of the sources of CO in air are :

(*i*) Incomplete combustion of carbon, fossil fuel or carbon containing compounds.

$$2C + O_2 \longrightarrow 2CO$$

For example, the complete combustion of butane requires 6.5 moles of O_2 per mole of butane. If only 6.0 moles of O_2 are present, then 1 mole of CO and 3 moles of CO_2 are formed.

$$C_4H_{10}\,(g) + \tfrac{13}{2}\,O_2\,(g) \longrightarrow 4CO_2\,(g) + 5H_2O\,(l)$$

$$C_4H_{10} + 6O_2\,(g) \longrightarrow 3CO_2\,(g) + CO(g) + 5H_2O\,(l)$$

(*ii*) Reaction of carbon dioxide and carbon containing compounds at high temperatures in industrial processes such as blast furnace.

$$CO_2 + C \longrightarrow 2CO$$

(*iii*) Dissociation of carbon dioxide at high temperatures :

$$2CO_2 \rightleftharpoons 2CO + O_2$$

Some natural processes such as volcanic activity, natural gas emission, electrical discharge during storms, marsh gas production, seed germination, etc. release some CO in the atmosphere.

The main contribution of CO in air pollution is from human activity. Of the total carbon monoxide content in atmosphere, **about 74% is contributed by automobile exhaust (motor vehicles, aircraft, rail, road).** About 16% is contributed by forest fires and agriculture burning (burning of forest debris, crop residues, weeds and other vegetation). Industrial processes mainly iron and steel industries, paper, petroleum industries contribute about 9.6% of CO in atmosphere.

Sinks of CO

Though human activities are releasing CO in atmosphere and it is expected to double its concentration in surrounding atmosphere every 5 years. However, the actual increase in CO in atmosphere is less because of some natural sinks.

(*i*) Soil is the major sink for CO. Some microorganisms in soil remove CO from the atmosphere.

(*ii*) Some of the species in atmosphere such as hydroxyl (HO) and perhydroxyl (HOO) radicals, atomic oxygen and ozone help in the oxidation of CO to CO_2 and consequently, remove it from the atmosphere.

Harmful effects of Carbon monoxide

1. Effects of CO on human health

Carbon monoxide is very toxic because it combines with haemoglobin in the blood preventing

its function as an oxygen carrier. It is particularly dangerous because it is odourless and therefore, is not easily detected. Haemoglobin (Hb) in the blood combines with oxygen and forms oxyhaemoglobin by a reversible process :

$$Hb + O_2 \rightleftharpoons HbO_2$$

Oxyhaemoglobin formed in the lungs is carried to the different cells in the body and gives oxygen. However, carbon monoxide combines more readily than O_2 with haemoglobin of blood to form carboxy haemoglobin which is about 300 times more stable than the oxygen-haemoglobin complex. Therefore, when CO is enhaled along with air, it combines with haemoglobin to form a stable compound carboxy haemoglobin, (HbCO).

$$Hb + CO \longrightarrow HbCO$$

As a result, the amount of haemoglobin for transport of O_2 decreases and it reduces blood's capacity for carrying oxygen. When the concentration of carboxyhaemoglobin in blood reaches about 3–4 percent, the oxygen carrying capacity of blood is greatly reduced.

This deficiency of oxygen results into many harmful effects such as reduction in awareness and judgement, dizziness, weak eye sight, headache, nervousness and cardiovascular disorders.

At higher concentrations of CO, suffocation, loss of consciousness or even death after several hours may occur. This is the reason why pregnant women who have the habit of smoking are advised not to smoke as increased CO level in blood may induce premature birth of the baby, spontaneous abortions or deformed babies. It is so poisonous that within half an hour, 1300 ppm is fatal.

⇒ Because of harmful effects of carbon monoxide, *it is dangerous to sleep in a closed room with a coke fire burning inside on a cold winter night*. When coke burns in an insufficient supply of oxygen (due to closed room), a lot of carbon monoxide is produced. This can cause poisoning and may lead to death.

Effects of CO on Plants

Carbon monoxide has detrimental effects on plants when exposed for longer times. It inhibits the nitrogen fixing ability of bacteria. It also affects leaf drop, leaf curling, decrease in leaf size and premature ageing of the plants.

Control of CO

The major sources of CO air pollution are human activities. The internal combustion engine is the primary source of CO emission. The exhaust of internal combustion engine consists of a mixture of CO, oxides of nitrogen (NO_x), hydrocarbons (H_c) and particulate matter. The variation of fuel-air ratios has significant effect on the constituents of exhaust gases. It has been observed that as the air-fuel ratio increases (leaner in fuel), the concentration of CO decreases. Therefore, CO-emissions may be lowered by using a cleaner air-fuel mixture. For example, when air-fuel ratio (wt./wt.) is more than about 16 : 1 in internal combustion engines, they emit virtually no CO.

Some of the **important attempts** which have been made for the control of CO pollution are given below :

(*i*) Internal combustion engines are modified to reduce the amount of pollutants formed during fuel combustion. The presence of excess air ensures complete combustion of CO and hydrocarbons to CO_2. Automobile carburettors are adjusted and cleaned regularly to the proper fuel-air ratios.

(*ii*) Some exhaust system reactors are developed which will complete the combustion process and decrease the amount of CO.

(*iii*) Catalytic converters can be fitted into exhaust pipes to cut down the CO emission. These anti-pollution catalysts eliminate the pollutants from exhaust gases before they are discharged into the atmosphere.

(*iv*) Substituted fuels for gasoline which will give low concentration of pollutants upon combustion are being tried. Natural gas in compressed form (CNG) and in liquefied form (LPG) has been used as a fuel. Though there are pollution free fuels, yet they are less economical and difficult to store and distribute.

(*v*) Attempts are being made to develop pollution free energy sources such as electric power, gas turbines, solar cells etc. However, these are less economical as compared to gasoline.

(*b*) Carbon dioxide (CO_2)

Carbon dioxide is a normal and essential component of the atmosphere. Animals exhale it. Therefore, it is vital to all forms of plant and animal life. It is normally not a pollutant. It is not an important contributor to acid rain. It can cause acidity when it dissolves in water, but it is relatively less soluble in water than the oxides of nitrogen and sulphur. Normally, it forms about 0.03% by volume of the atmosphere. However, human activities are changing the balance established by nature's carbon cycle. With the increased use of fossil fuels, a large amount of carbon dioxide gets released into the atmosphere. As a result, the concentration of CO_2 in the atmosphere is increasing to an alarming extent.

Therefore, there is need to keep balance of CO_2 in the atmosphere.

Sources

The main sources of CO_2 in atmosphere are :

(*i*) Carbon dioxide is released into the air by respiration.

(*ii*) Incomplete combustion of fossil fuels and carbon containing compounds.

$$C + O_2 \longrightarrow CO_2$$

(*iii*) Many industrial processes also produce a lot of carbon dioxide. For example, decomposition of limestone during manufacture of cement releases lot of carbon dioxide into the atmosphere.

(*iv*) Carbon dioxide is also produced by biological decay of plants.

(*v*) Carbon dioxide gas is also emitted during volcanic eruptions.

Sinks of CO_2

The main sinks for CO_2 are natural processes. Ocean is an important sink of carbon dioxide. It contains most of the dissolved CO_2 in the form of carbonates, bicarbonates and organic compounds.

The carbon dioxide of the atmosphere is also removed from the atmosphere by photosynthesis process of plants. In a balanced ecosystem, the additionally released CO_2 in the atmosphere is regularly removed by green plants for the photosynthesis process and they in turn emit oxygen, thus maintaining the cycle.

Effects of CO_2

Normally carbon dioxide is harmless and is not a pollutant. However, the increasing concentration of CO_2 may affect the atmosphere, causing undesirable change in climate. This effect is known as **greenhouse effect** (discussed later).

Control of CO_2

The major sources of CO_2 are vehicles, plants and industries while the sinks are ocean and plants. The balance can be maintained by the following steps :

(*i*) The release of CO_2 from various industrial processes should be controlled.

(*ii*) The production of CO_2 from vehicles exhaust should be checked.

(*iii*) To adjust the balance of CO_2 in atmosphere, the main sink of CO_2 *i.e.*, forests should be developed.

2. Oxides of Nitrogen (NO_x)

A number of oxides of nitrogen (NO_x) such as nitrous oxide (N_2O), nitric oxide (NO), nitrogen dioxide (NO_2), N_2O_3 (dinitrogen trioxide) and N_2O_5 (dinitrogen pentoxide) are entering the atmosphere due to natural sources and human activities. Out of these, only two oxides, NO and NO_2 are considered as pollutants.

Nitric oxide (NO) is colourless, odourless gas and nitrogen dioxide (NO_2) is reddish brown gas having pungent suffocating odour.

The irritant red haze in traffic and congested places is due to oxides of nitrogen.

Sources of NO_x

Dinitrogen and dioxygen are the main constituents of air. These gases donot react with each other at normal temperature. But at high altitudes when lightening strikes, they combine to form oxides of nitrogen.

The important sources of NO and NO_2 are given below :

(*i*) The two oxides of nitrogen NO and NO_2 come in atmosphere from the combustion at high temperature (above 1483K) in automobile engines and thermal generating stations. The basic reactions leading to the formation of these oxides of nitrogen are :

$$N_2(g) + O_2(g) \overset{1483K}{\rightleftharpoons} 2NO(g)$$

NO reacts instantly with oxygen to give nitrogen dioxide.

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$$

Rate of production of NO_2 is faster when nitric oxide reacts with ozone as in the stratosphere.

$$NO(g) + O_3(g) \longrightarrow NO_2(g) + O_2(g)$$

(*ii*) Many industrial processes also release oxides of nitrogen in the atmosphere.

(*iii*) The natural sources of oxides of nitrogen are bacterial action in soil, forest fire and lightning.

Sinks of NO_x

Many natural processes acts as sink for oxides of nitrogen. These oxides are inherently unstable and decompose to N_2 and O_2 after some time. Therefore, the concentration of nitrogen oxides in the atmosphere tends to remain low. Some natural processes and photochemical reactions also take care of NO_x in the atmosphere and serve as sinks. The end product of these reactions is HNO_3. The probable mechanism for the change of NO_x to nitric acid are :

(*i*)
$$2NO + O_2 \longrightarrow 2NO_2$$
$$3NO_2 + H_2O \longrightarrow 2HNO_3 + NO$$
$$4NO_2 + 2H_2O + O_2 \longrightarrow 4HNO_3$$

(*ii*)
$$NO_2 + O_3 \longrightarrow NO_3 + O_2$$
$$NO_3 + NO_2 \longrightarrow N_2O_5$$
$$N_2O_5 + H_2O \longrightarrow 2HNO_3$$

The nitric acid acts as a temporary sink and it comes in the form of nitrate salts in acid rainfall or in dust.

Harmful effects of NO_x

The irritant red haze in the traffic and congested places is due to the oxides of nitrogen. The main harmful effects of oxides of nitrogen are :

1. NO is biologically less active and less toxic than NO_2 and therefore, does not have a significant adverse effect on human health even at high concentrations. However, it is oxidised by oxygen or

ozone to nitrogen dioxide which is extremely toxic to living tissue. Like CO, NO binds to haemoglobin and decreases oxygen transport efficiency of blood.

$$2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$$

$$NO(g) + O_3(g) \longrightarrow NO_2(g) + O_2(g)$$

2. The oxides of nitrogen cause damage to the leaves of plants. Exposure of plants to NO_x causes leaf spotting and breakdown of plant tissues. Excessive concentration (10 ppm) of NO causes decrease in the rate of photosynthesis.

3. The sunlight reacts with nitrogen dioxide to produce highly active oxygen atoms.

$$NO_2 \xrightarrow{\text{Sunlight}} NO + O$$

The active oxygen attacks traces of hydrocarbons in the air and produces irritants which is called *photochemical smog*. This is a health hazard.

4. Acute exposure to NO_2 can also cause damage to human health. Nitrogen dioxide is a lung irritant and can lead to acute respiratory disease in children.

5. The nitrogen oxides are harmful to various textile fibres and metals. These also cause fading of dyes used in textiles.

Control of Nitrogen oxides

The important factors in the control of oxides of nitrogen are :

(*i*) NO in vehicular exhausts is converted into N_2 and traces of NH_3 with the help of some catalyst (platinum).

(*ii*) Nitrogen oxides in fuel gases can be removed by alkaline scrubbing solutions using $Ca(OH)_2$ and $Mg(OH)_2$.

(*iii*) The nitrogen oxides can also be removed by acidic scrubbing. This process also removes SO_2. This involves the following steps :

(*a*) The flue gases coming from power plants or industrial units contain NO, NO_2 and SO_2. These are introduced into an oxidizer in which the following reaction occurs :

$$NO_2 + SO_2 + H_2O \longrightarrow H_2SO_4 + NO$$

(*b*) The NO and NO_2 react to form N_2O_3 which is scrubbed by H_2SO_4 in a scrubber.

$$NO_2 + NO \longrightarrow N_2O_3$$

$$N_2O_3 + 2H_2SO_4 \longrightarrow 2NOHSO_4 + H_2O$$

The scrubbed flue gas is released to the atmosphere.

(*c*) The reaction product, $NOHSO_4$ is then decomposed in a separate chamber called decomposer and the resulting H_2SO_4 is recycled to the scrubber.

$$2NOHSO_4 + \frac{1}{2}O_2 + H_2O \longrightarrow 2H_2SO_4 + 2NO_2$$

(*d*) NO_2 is then converted to HNO_3 in a reactor.

$$3NO_2 + H_2O \longrightarrow 2HNO_3 + NO$$

Excess of NO and NO_2 is recycled into the oxidiser.

3. Oxides of Sulphur (SO_x)

Oxides of sulphur are probably the most harmful of the common gaseous pollutants. *Sulphur dioxide is the main pollutant among sulphur oxides.* It is a colourless gas with a pungent odour. It is generally accompanied by little of SO_3 obtained by partial oxidation of SO_2.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

Under humid conditions, SO_3 reacts with water vapour to form H_2SO_4 droplets.

$$SO_3(g) + H_2O(l) \rightleftharpoons H_2SO_4(l)$$

Sources of Sulphur dioxide

Some of the important sources of sulphur dioxide in atmosphere are :

(*i*) Most of the sulphur dioxide in atmosphere originate through the combustion of fossil fuels which contain some sulphur.

(*ii*) The atmosphere contains H_2S by decay of organic matter. The H_2S gets readily converted into SO_2 by the following reaction :

$$H_2S + \frac{3}{2}O_2 \longrightarrow SO_2 + H_2O$$

(*iii*) Large amounts of SO_2 are added to the atmosphere during ore roasting processes of sulphur ores. For example, SO_2 is produced during roasting of metallic sulphide ores such as pyrites (FeS_2), copper glance (Cu_2S), galena (PbS), zinc blende (ZnS), etc.

$$2ZnS + 3O_2 \longrightarrow 2ZnO + 2SO_2$$

Zinc blende

$$3Cu_2S + 3O_2 \longrightarrow 6Cu + 3SO_2$$

Copper glance

(*iv*) Volcanic sources also contribute significantly to the SO_2 in atmosphere.

The combustion of any sulphur containing material results in the formation of SO_2 and SO_3. Sulphur dioxide is the major constituent (about 97%) of the mixture.

Sinks of SO_2

Sulphur dioxide in air can undergo several reactions and therefore, can be removed. A part of SO_2 combines with water droplets to form sulphurous acid.

$$SO_2 + H_2O \longrightarrow H_2SO_3$$

It can also be oxidised to sulphur trioxide in air but uncatalysed oxidation of sulphur dioxide is slow. But because the polluted air often contains particulate matter, it catalyses the oxidation of sulphur dioxide to sulphur trioxide.

$$2SO_2 + O_2 \longrightarrow 2SO_3$$

The reaction can also be promoted by ozone and hydrogen peroxide.

$$2SO_2 + O_3 \longrightarrow SO_3 + O_2$$

Sulphur trioxide combines with water vapour to form droplets of sulphuric acid.

$$SO_3 + H_2O \longrightarrow \underset{\text{Aerosol droplet}}{H_2SO_4} \longrightarrow (H_2SO_4)_n$$

The sulphuric acid comes down in the form of acid rain and gives rise to a phenomenon known as acid rain (discussed later on).

Effects of SO_2

Sulphur dioxide and its compounds (formed from SO_2 such as SO_3, H_2SO_4 or sulphates) are dangerous air pollutants. These have dangerous effects on human life. Some of the harmful effects are :

1. SO_2 effects respiratory tract producing nose, eye and lung irritation. It has been reported that lower concentration of SO_2 causes respiratory diseases *e.g.*, asthama, bronchitis, emphysema in human beings. It also causes irritation to the eyes resulting in tears and redness. High concentration of SO_2 may cause lung diseases and lung cancer. SO_2 has been considered the most serious single air pollutant causing many health hazards.

2. Atmospheric SO_2 is also harmful for plants. It damages vegetable crops and affects plant growth and nutrient quality of plant products. The exposure of plants to SO_2 causes damage to leaf tissues and causes **chlorosis** (a bleaching or yellowing of normally green portions of the leaves). In areas, having high levels of SO_2 pollution, and formation of H_2SO_4, may damage the plants.

3. The marble and limestone, both forms of calcium carbonate ($CaCO_3$) are attacked by SO_2 and H_2SO_4. These react as :

$$CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + CO_2 + H_2O$$

This causes deterioration of buildings, statues, etc.

4. The oxides of sulphur cause fading and deterioration of fabric, leather and paper.

5. They affect the colour of the paints.

Control of SO_2 pollution

The various methods to control SO_2 pollution are given below :

(*i*) A number of processes are being used to remove sulphur from fuels before combustion.

(*ii*) Sulphur dioxide may be removed from flue gases. It can be easily eliminated by using chemical scrubbers.

Some of the methods to remove SO_2 chemically from the flue gases are :

(*a*) The most widely used method is limestone treatment in which finely divided limestone is directly introduced to the boiler. In this method, heat calcines the limestone forming quick lime. Quicklime reacts with SO_2 in the flue gas forming calcium sulphate.

$$CaCO_3 \longrightarrow CaO + CO_2(g)$$

$$CaO + SO_2 + \frac{1}{2}O_2 \longrightarrow CaSO_4$$

Solid $CaSO_4$ is removed and disposed off. However, the method is economical but it poses a problem of waste disposal.

(*b*) Sulphur dioxide produced may be passed through a lime slurry. This process is known as lime slurry scrubbing.

$$Ca(OH)_2 + SO_2 \longrightarrow CaSO_3 + H_2O$$

The waste ($CaSO_3$) from this method can be used to prepare *gypsum* by oxidation of $CaSO_3$.

$$CaSO_3 + \frac{1}{2}O_2 + 2H_2O \longrightarrow CaSO_4.\,2H_2O$$

(*c*) Sulphur dioxide may be removed by first treating with sodium hydroxide and then with calcium hydroxide as:

$$2NaOH + SO_2 \longrightarrow Na_2SO_3 + H_2O$$
$$Ca(OH)_2 + Na_2SO_3 \longrightarrow CaSO_3 + 2NaOH$$

In this method, the expensive sodium hydroxide solution is regenerated with inexpensive lime.

(*iii*) Alternative energy sources such as hydroelectric plants and nuclear power plants may be used in place of thermal power plants using burning of coal (containing sulphur). However, these are not economical.

4. Hydrocarbons

Many hydrocarbons of low molecular mass are gases or volatile liquids and are present in air at ordinary temperature. Among these, methane is the most abundant hydrocarbon pollutant.

Sources of hydrocarbons

(*i*) Hydrocarbons are formed by incomplete combustion of fuel used in automobiles.

(*ii*) Methane is released into the air in large quantities by the anaerobic decomposition of organic matter present in soil, water and sediments.

$$\underset{\text{Organic matter}}{2CH_2O} \xrightarrow{\text{bacteria}} CH_4 + CO_2$$

(*iii*) Evaporation of organic solvents such as benzene, toluene, etc. during industrial operations add to hydrocarbon pollution.

(*iv*) Some hydrocarbon pollution also takes place due to burning of fuels such as coal, wood, kerosene, etc.

(*v*) Some trees also emit large quantities of hydrocarbons into the air.

Effects of hydrocarbons

(*i*) Hydrocarbons are carcinogenic and therefore cause cancer.

(*ii*) They harm plants by causing ageing, breakdown of tissues and shedding of leaves, flowers and twigs.

(*iii*) Due to their photochemical reactions with oxygen and oxides of nitrogen, they form photochemical oxidants and photochemical smog. This has very hazardous effect on the human being and plants.

B. PARTICULATES IN AIR POLLUTION

1. Particulates

The small sized solid particles and *liquid droplets which range in size from* 2×10^{-10} *m (0.0002 μm) to* 5×10^{-4} *m are collectively* called as **particulates.** These particles are usually individually not visible to the naked eye. However, small particles often collectively form a haze that restricts the visibility. The particulate matter in the range 0.001 to 10 mm range is commonly visible as suspended in the air near the sources of pollution.

These particulates include carbon (soot), metals, metal salts, cement dust, fly ash, hydrocarbons, soil dust, pulverized coal, asbestos dust, mineral particles, etc.

The particulates in the atmosphere may be **viable** or **non-viable.** The **viable particulates** are the small living organisms which are dispersed in the atmosphere. These include bacteria, moulds, fungi, algae, etc. Some of these viable particulates cause allergic reactions on human beings. Fungi can also cause plant diseases.

Non-viable particulates are formed either by the breakdown of large materials or by the condensation of minute particles and droplets.

Types of Particulates and their Sources

There are four types of non-viable particulates in the atmosphere injected into the atmosphere through human activity.

1. Smoke

These are very small soot particles. These consist of solid or mixture of solid and liquid particles formed during combustion of organic matter. Oil smoke, tobacco smoke and carbon smoke from burning fossil fuels, garbage and dry leaves are typical examples of this type of particulate materials. Their common sources are :

(*i*) Carbon particles are produced in the atmosphere when fossil fuels (coal, fuel oil, natural gas, wood, etc.) are burnt in an insufficient supply of oxygen.

(*ii*) Forest fires, coal refuse burning and agriculture burning also produce a lot of smoke.

(*iii*) Many industries also release carbon particles in the atmosphere.

(*iv*) Carbon particles are also produced in the atmosphere due to inefficient burning of fuel in vehicles.

2. Mists

These are suspensions of liquid particles in air which arise because of chemical reactions and condensation of vapours in air. For example, mists are produced by the particles of the spray liquids. The common examples are portions of herbicides and insecticides which miss their targets and travel through the air to form mists. Similarly, sulphuric acid mist is produced when SO_3 present in the atmosphere comes in contact with moisture.

3. Fumes

These are condensed vapours. For example, fumes are generally produced by the condensation of vapours during sublimation, distillation, boiling and several other chemical reactions. Generally, organic solvents, metals and nonmetallic oxides constitute fumes.

4. Dust

The solid particles (*over 1μm in diameter*) *suspended in the air* are called **dust.** These particles enter into atmosphere from natural, domestic and industrial sources. These enter the atmosphere by volcanic eruptions, blowing of dust by wind, mining operations, crushing and grinding, etc. The non-viable dust particulates in the atmosphere consist of ground limestone, sand tailings from floatation pulverised coal, cement, fly ash and silica dust.

These above types of particulates consist of different types of metals and their compounds and organic particulates as discussed below :

(*a*) Metal particles. These are released into the atmosphere by various metal finishing processes. The common metallic particles in air are lead, mercury, chromium, arsenic, zinc, cadmium, nickel, iron, etc. Although these metallic particles are present in air in very small amounts yet some of these are very dangerous to living organisms.

(*b*) Metal oxides. Metal oxides are released into the atmosphere during combustion of fuels containing metallic compounds. For example, particulate Fe_3O_4 is produced by the combustion of coal containing iron pyrite as :

$$3FeS_2 + 8O_2 \longrightarrow Fe_3O_4 + 6SO_2$$

Power plants using vanadium rich residual oil are sources of V_2O_5 pollutants.

(*c*) Metal salts. Burning of coal gives $CaCO_3$ in ash which is partly converted into CaO. Sulphuric acid droplets in the atmosphere combine with basic pollutants CaO or NH_3 to form salt particulates.

$$H_2SO_4 + CaO \longrightarrow CaSO_4 + H_2O$$
$$H_2SO_4 + 2NH_3 \longrightarrow (NH_4)_2SO_4$$

(*d*) Tetraethyl lead. It is a source of lead salts in the atmosphere. Tetraethyl lead is added to gasoline to improve its antiknocking property. It is oxidised to PbO which tends to deposit on spark plugs and values. This is undesirable and is a source of air pollution.

(*e*) Fly ash. *These are the small ash particles formed by the combustion of fossil fuels which are carried into the air by gases produced during combustion.* These enter into the atmosphere from power plants, smelters and mining operations.

(*f*) Asbestos dust. This originates from industrial units manufacturing asbestos sheets, gaskets, ropes, etc. Asbestos insulation and asbestos flooring also add towards asbestos dust in the atmosphere.

(*g*) Organic particulate matter. Organic particulates are released in the air when hydrocarbons present in coal and oil are oxidised. Among these polycyclic aromatic hydrocarbons (PAH) containing fused benzene rings are important components of organic particulate because of their carcinogenic nature.

These particles are readily adsorbed on the surface of soot particles present in the atmosphere and therefore are serious health hazards.

Effects of Particulates

The effects of particulate pollutants depend upon the size of the particles. The coarser particles of size more than 5 microns are likely to lodge in the nasal passages whereas the smaller ones are more likely to penetrate into the lungs. The rate of penetration is inversely proportional to the size of the particles. Some of these particles are carcinogens. Continuous inhaling of these small particles for long periods of time irritates the lungs and causes 'scarring' or 'fibrosis' of the lung lining. This type of disease is very common in industrial settings and is known as "**pneumoconiosis".**

Different types of lung diseases are caused by different types of particulates. For example, asbestos causes **asbestosis,** the dust containing silica (SiO_2) causes **silicosis**, the workers working in coal mines suffer from **black lung disease,** whereas textile workers suffer from **white lung disease,** etc.

Lead particulates are highly poisonous and have a serious effect on brain central nervous system and cause cancer.

The suspended particulate matter in the atmosphere reduce visibility and influence weather also. These reduces the amount of light rays reaching the surface of the earth and therefore, lowers the temperature of the earth. By blocking the sunlight, they cause drop in the earth's temperature by providing condensation nuclei, they contribute to increase fog and rain in cities.

The large concentration of these particles spoil many articles and blackens buildings. These particulates have large surface area and hence offer good sites for adsorption of many harmful inorganic and organic matter. Gases like SO_2, PAH particles, toxic metals (Be, Pd, Cd, Cr, etc.) are adsorbed on the surface of soot as shown below.

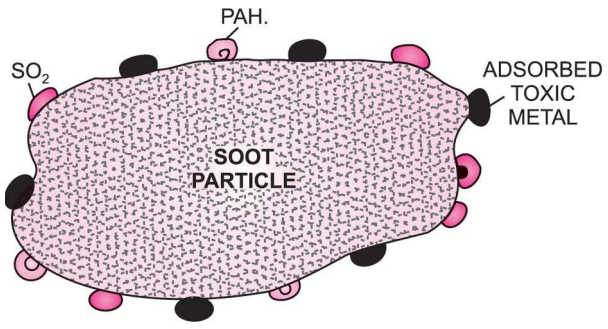


Fig. 4. Soot particle with toxic adsorbates.

Control of Particulates

Various methods are employed to reduce the presence of carbon and other particulates in the atmosphere.

(*i*) Effluent gases from the industries are led into a chamber where the velocities of these gases decrease so that dust or droplets get settled. This method is suitable for particles which are settled readily and is not suitable for the fine particles which require longer settling time.

(*ii*) The carbon and other dust particles are removed by **electrostatic precipitator.** This method is based on the principle that the particles acquire electrical charges when subjected to an electric field. In this method, two electrodes are fitted against the inside walls of the smoke stack (Fig. 5). When high voltage (30,000 – 100,000 V) is applied, an electric discharge takes place across the stack and as a result, air in the stack is ionized. The ionized air consists of ions and free electrons. The free electrons get attached to the gaseous particles moving up the stack. The particles get negatively charged and are attracted to the positive electrode located on the inner wall of the stack and settle down there. These can be dislodged from the electrodes by water or vibration of the electrodes and are collected in a reservoir. In this way about 99% of the particulate matter gets removed from the fuel gases.

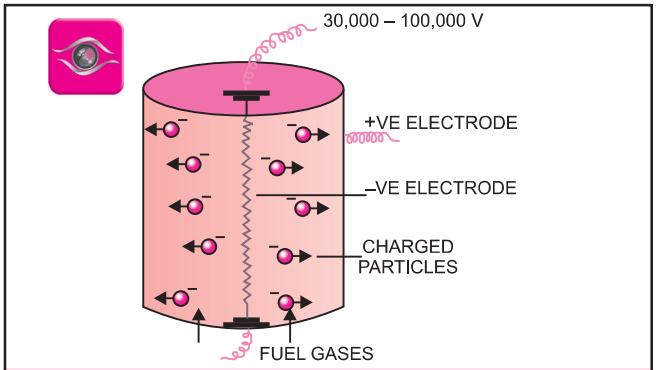


Fig. 5. An electrostatic precipitator.

(*iii*) The solid, liquid or gaseous particulates can be removed by spraying water from spray chambers.

(*iv*) Large amount of particles can be collected in cyclone collectors.

SMOG

Smog is a mixture of smoke, dust particles and small drops of fog. It is a major air pollutant in big cities. This is the best known example of air pollution that occurs in many cities throughout the world. The small drops of smog contains poisonous gases produced by burning of fuels in homes, factories and automobiles.

Smoke + Fog (Containing harmful gases) $\longrightarrow$ Smog

Smog is of two types :

(*i*) *Classical smog,* and

(*ii*) *Photochemical smog.*

1. Classical smog

This type of smog is formed by the combination of smoke, dust and fog containing sulphur dioxide from polluted air. It is formed in those areas which have cool and humid climate and where sulphur dioxide in the air is very high. This is also called **chemical smog.** This type of smog was observed in 1962 in London. The city remained covered with smog for 5 days and it caused deaths of many persons. Chemically, it is a reducing mixture so it is also called **reducing smog**.

2. Photochemical smog

This type of smog is formed by the combination of smoke, dust and fog with an air pollutant in the atmosphere as a result of photochemical reaction. It occurs in those areas which have warm, dry and sunny climate. It has high concentration of photochemical oxidants. These are produced when some of the primary pollutants interact under the influence of sunlight. It occurs in warm, dry and sunny climate. It develops in cities in which the atmosphere is loaded with large quantities of automobile exhausts, stagnant air masses and intense sunlight. It has been observed in cities which have sunny, warm and dry climates such as Los Angeles and Denver in U.S.A. Therefore, it was earlier called ***Los Angeles smog***. The photochemical smog is chemically oxidising because it has high concentration of oxidants. It is characterized by brown hazy irritating fumes. As a result of photochemical smog having characteristic brown haze, the cities such as Los Angeles are sometimes called ***brown air cities.***

Formation of photochemical smog

The chemistry of formation of photochemical smog centres around nitric oxide (NO). The formation of photochemical smog can be understood by the following steps :

(*i*) During the early morning before the sun rise, the automobile exhaust emits CO, hydrocarbons and oxides of nitrogen. The NO reacts with oxygen to produce NO_2, a yellowish brown gas.

(*ii*) As the sun rises, ultra-violet and visible radiations fall on the earth. The NO_2 absorbs energy from sunlight and breaks up into nitric oxide and free reactive oxygen atoms.

$$NO_2 \xrightarrow{h\nu} NO + \underset{\text{(Reactive oxygen)}}{O}$$

Some of these oxygen atoms combine with O_2 in the air to produce ozone gas.

$$O_2 + O \longrightarrow O_3$$

Ozone reacts with NO to form NO_2 and O_2

$$O_3 + NO \longrightarrow NO_2 + O_2$$

NO_2 again absorbs U.V. radiations and the entire cycle starts again. Both NO_2 and O_3 are strong oxidizing agents and can react with unburnt hydrocarbons (from exhaust of automobiles) to form organic free radicals. The formation of organic free radicals results into a number of chain reactions producing many undesirable compounds (such as formaldehyde, acrolein, organic peroxides, organic hydroperoxides, peroxyacyl nitrates etc.) which constitute photochemical smog. It also includes H_2O_2. The brownish haze of photochemical smog is largely due to brown colour of NO_2

$$3CH_4 + 2O_3 \longrightarrow \underset{\text{Formaldehyde}}{3HCHO} + 3H_2O$$

Acrolein and peroxyacetylnitrate (PAN) are very noxious substances.

$$\underset{\text{Acrolein}}{CH_2{=}CHCHO} \qquad \underset{\text{Peroxyacetylnitrate (PAN)}}{CH_3{-}\overset{\overset{O}{\|}}{C}{-}OONO_2}$$

For example, peroxyacylnitrate (PAN) is a constituent of photochemical smog which irritates eyes. This is formed from aldehydes, in which the reaction is initiated by hydroxyl radical, OH• formed by the reaction of excited atomic oxygen with water, or photolysis of nitrous acid.

$$H_2O + O \longrightarrow 2HO^{\bullet}$$

$$HNO_2 \xrightarrow{h\nu} HO^{\bullet} + NO$$

The $OH^{\bullet}$ leads to the formation of PAN as :

$$\underset{\text{Aldehyde}}{RCHO} \xrightarrow{OH^{\bullet}} \underset{\text{(Acyl radical)}}{R{-}\overset{\overset{O}{\|}}{C}{\bullet}} \xrightarrow{O_2} \underset{\text{(Peroxyacyl radical)}}{R{-}\overset{\overset{O}{\|}}{C}{-}OO^{\bullet}} \downarrow \quad R{-}\overset{\overset{O}{\|}}{C}{-}OONO_2 \ \text{(PAN)}$$

Harmful effects of Photochemical Smog

The three main components of photochemical smog are ozone, nitrogen oxides and organic derivatives (such as acrolein, formaldehyde, PAN etc.). Each of these have hazardous effects of smog.

1. Pungent smelling smog containing ozone is very toxic. It can cause coughing, wheezing, bronchial constriction and irritation to the respiratory mucous system.

2. Aldehydes and peroxyacylnitrate (PAN) components of photochemical smog cause irritation of eyes and affects respiratory tract of human beings.

3. It reduces visibility causing nose, throat and eye irritation. It may lead to several chronic diseases of eyes, heart and lungs.

4. It affects human health and comfort.

5. Photochemical smog affects plant growth and damages plants. Ozone is known to cause damage to

vegetation and reduction in plant growth and productivity of crop. PAN has also highest toxicity to plants. It attacks younger leaves and causes bronzing and glazing of their surfaces.

6. Materials are also adversely affected by photochemical smog. For example, rubber has strong affinity for ozone and is cracked and aged by smog.

Control of Photochemical Smog

Efforts are being continuously made to control or reduce the formation of photochemical smog. This can be done by controlling the primary precursors of photochemical smog such as NO_2 and hydrocarbons and the secondary precursors such as ozone and PAN. For this, efficient catalytic converters are designed and installed in the automobiles to reduce photochemical smog because reduce the smog and prevent the release of nitrogen oxides and hydrocarbons to the atmosphere. Certain plants such as Pinus, Juniparus, Quercus, Pyrus and Vitis can metabolise nitrogen dioxide and therefore, plantation of these plants could help to reduce photochemical smog.

Photochemical smog can also be suppressed by certain compounds which trap free radicals. These are sprayed in the atmosphere where they generate free radicals which combine with free radical precursors of photochemical smog and consequently reduce it.

ACID RAIN

Fossil fuels contain compounds of sulphur and nitrogen in addition to carbon. The combustion of fuels contributes significantly to atmospheric pollution. The burning of fossil fuels gives CO_2. The gaseous CO_2 dissolves in water droplets to form weak acid, carbonic acid.

$$CO_2(g) + H_2O(aq) \longrightarrow H_2CO_3(aq)$$

$$H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

Rain water normally has pH of 5.6 due to the formation of H^+ ions from the reaction of rain water with carbon dioxide present in the atmosphere. When the pH of the rain water falls below 5.6, it becomes acidic and is called **acid rain.** Thus, acid rain means the way in which acid from the atmosphere is deposited on the earth's surface.

However, CO_2 is not the major component of acid rain because it is not soluble in water like the oxides of sulphur and nitrogen. The oxides of nitrogen and sulphur undergo many photochemical reactions in atmosphere and form HNO_3 and H_2SO_4 acids. During rains, these acids fall to the earth with rain. This polluted rain is called *acid rain.* The main reactions are :

Nitric acid is formed as :

$$NO + O_3 \longrightarrow NO_2 + O_2$$

$$NO_2 + 2O_2 \longrightarrow NO_3 + O_3$$

$$NO_2 + NO_3 \longrightarrow N_2O_5$$

$$N_2O_5 + H_2O \longrightarrow 2HNO_3$$

or $$4NO_2(g) + O_2 + 2\,H_2O(l) \longrightarrow 4HNO_3(aq)$$

Similarly, sulphuric acid is formed as :

$$2SO_2(g) + O_2(g) + 2H_2O(l) \xrightarrow[\text{particles}]{\text{Soot}} 2H_2SO_4(aq)$$

Thus, **acid rain is the rain water containing acids such as nitric acid and sulphuric acid which are formed by the oxides of nitrogen and sulphur present in air as pollutants.**

The presence of soot particles in atmosphere speeds up the oxidation process. Due to the presence of HNO_3 and H_2SO_4 in rain the pH of water decreases. Ammonium salts are also formed and can be seen as an atmospheric haze (aerosol of fine particles). Aerosol particles of oxides or ammonium salts in rain drops result in wet deposition. SO_2 is also adsorbed directly on both solid and liquid ground surfaces and this is deposited as dry deposition.

Harmful effects of Acid Rain

Acid rain is very damaging. It is toxic to vegetation, human life and aquatic life. Some of its harmful effects are:

1. It causes extensive damage to buildings and sculptural materials of marble, limestone, slate, etc. These materials react with rain water and get damaged.

$$CaCO_3 + H_2SO_4 \rightleftharpoons CaSO_4 + CO_2 + H_2O$$

As a result of acid rain, the invaluable statues and buildings deteriorate. In Greece and Italy, many invaluable statues have been partially facaded. The Taj Mahal of India is facing the same problem.

2. When acid rain falls and flows as ground water to reach rivers, lakes, etc, it affects plants and animal life in aquatic ecosystem. The acid rain has also caused elimination of life from some fresh water lakes by destroying the living bodies.

3. The rain water also corrodes metals and damages iron and steel structures.

4. Acid rain is harmful for agriculture, trees and plants because it dissolves and washes away nutrients needed for their growth. Therefore, it damages leaves of trees and plants and retard the growth of forests. It also retards the growth of certain crops such as peas, potato, raddish, carrot, beans, spinach, etc.

5. Acid rain dissolves heavy metals from soils, rocks and sediments. The heavy metal ions such as copper, lead, mercury and aluminium leached from the soil enter well water and produce many toxic effects.

6. Acid rain corrodes water conduit pipes resulting in leaching of some heavy metals such as iron, lead and copper into our drinking water which have toxic effects.

Methods to reduce the formation of acid rain

Acid rain is due to emission of oxides of nitrogen and sulphur in the atmosphere. Therefore, to reduce the formation of acid rain, the emission of these gases has to be controlled. For this, the following steps should be taken :

(*i*) By using fossil fuels having less sulphur content in power plants and industries. For example, natural gas should be used than coal or coal containing lesser sulphur contents should be used.

(*ii*) By using less vehicles driven by fossil fuels.

(*iii*) By using catalytic convertors in cars so that exhaust gases are converted into nitrogen.

(*iv*) By using powdered limestone to neutralise the acidity of the soil.

Acid rain and Taj Mahal of India

The acid causes extensive damage to buildings and sculptural materials of marble, limestone, slate etc. The air in the city of Agra where Taj Mahal is located contains very high levels of oxides of sulphur and nitrogen. This causes acid rain and it reacts with marble ($CaCO_3$) of Taj Mahal

$$CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + H_2O + CO_2$$

As a result, the marble becomes pitted and weakened mechanically because the soluble salts are easily leached out by rain water. Therefore, the wonderful monument is being slowly eaten away and the marble is getting discoloured and lustreless. The same problem is being faced by Greece and Italy where the stone statues have been partially dissolved by acid rain.

To protect Taj Mahal, the Government of India has announced an action plan in 1995 to prevent the disfiguring of this historical wonder. This plan aims at clearing the air in the **Taj Trapezium,** an area which includes towns of Agra, Firozabad, Mathura and Bharatpur. Under this plan about more than 200 industries lying within this trapezium would shift over the use of natural gas or liquefied petroleum gas instead of coal or oil. A new natural gas pipeline would provide more than half a million cubic metres of natural gas a day to this area. The people living in this area will also be encouraged to use LPG in place of coal or kerosene oil. Even the vehicles plying on highways in the nearby areas of Taj Mahal would be encouraged to use diesel of low sulphur content.

STRATOSPHERIC POLLUTION : FORMATION AND DEPLETION OF OZONE LAYER

Ozone is an important constituent of the stratosphere at altitudes between 15 and 25 km. It is formed in the atmosphere by the decomposition of oxygen by ultra-violet radiation from the sun having wavelength shorter than 260 nm.

$$O_2\,(g) + h\nu \xrightarrow{UV} O\,(g) + O\,(g)$$

$$O\,(g) + O_2\,(g) \xrightarrow{UV} O_3\,(g)$$

Most atmospheric ozone is found in stratosphere where its concentration is about 10 ppm (parts per million) by volume. Ozone is thermodynamically unstable and decomposes into molecular oxygen. It has the important photochemical property of absorbing solar radiation between the wavelength of 200 nm and 300 nm.

$$O_3\,(g) + h\nu \longrightarrow O\,(g) + O_2\,(g)$$

The reactive atomic oxygen formed in the above reaction recombines with molecular oxygen to form ozone. This completes the ozone cycle. Thus, a dynamic equilibrium exists between the production and decomposition of ozone molecules

The thick layer of ozone is called **ozone blanket** because it is very effective in absorbing harmful ultra-violet rays given out by the sun. Therefore, the ozone layer is also known as **protective shield.** Since living cells can be destroyed by ultra-violet radiation, the ozone layer protects us from its damaging effects. If there were no ozone in the stratosphere,life on the earth would not be possible. Even a small decrease in the concentration of ozone could lead to an increased incidence of skin cancer.

Depletion of Ozone layer and its effects

Recently in 1980, scientists have observed a hole in the ozone blanket covering the upper atmosphere around Antarctica. Recent observations have also shown that the ozone layer diminishes over the south pole in spring during August-September to a greater extent year after year. This depletion of the protective blanket of ozone will cause a damaging effect because harmful ultra-violet rays can come to earth through this hole. The increased level of ultra-violet rays will result in damage to plants, animals, human beings and even inanimate matter posing great threat to ecosystem over the globe.

Thus, the depletion of ozone layer is a serious threat to mankind. Scientists believe that every 1% decrease in ozone leads to 2% increase in skin cancer due to exposure to sun's ultra-violet rays.

The depletion of ozone may be due to some *natural processes* or *industrial activities.*

Nitrous oxide (N_2O) occurs naturally at very trace levels in stratosphere. It can react with electronically excited oxygen atoms obtained by the ozone cycle to give NO.

$$N_2O + O^* \longrightarrow \underset{\text{Nitric oxide}}{2NO}$$
(Excited atomic oxygen)

This removes an oxygen atom needed by the ozone cycle and the product, NO can destroy a second ozone molecule which breaks up another cycle.

$$NO + O_3 \longrightarrow NO_2 + O_2$$
$$NO_2 + O \longrightarrow NO + O_2$$
$$\overline{O_3 + O \longrightarrow 2O_2}$$

Therefore NO is very damaging because just one NO molecule sets up a chain reaction which removes ozone again and again. There are similar ozone depleting chain reactions involving other stratospheric gases.

Chlorofluoro carbons and Ozone layer

Chlorofluoro carbons are compounds such as $CFCl_3$, CF_2Cl_2, CF_3Cl, commonly known as **freons.** These compounds are non-reactive, odourless, non-toxic, non- flammable, and thermally stable.

The large amount of these products are being extensively used in air conditioners, refrigerators, fire fighting materials, fast food packing materials, for sterilizing surgical instruments in medicinal products, in the production of plastic foam and by the electronic industries as cleaning solvents and are released in the atmosphere causing air pollution.

Once chlorofluorocarbons (CFCs) are released in the atmosphere, they mix with the normal atmospheric gases and ultimately reach the stratosphere. In stratosphere, they get broken down by powerful ultraviolet radiations releasing chlorine free radicals ($Cl^{\bullet}$). These released Cl free radicals cause a catalytic chemical reaction and cause significant depletion of stratospheric ozone layer.

$$CF_2Cl_2 + h\nu \longrightarrow Cl^{\bullet} + CF_2Cl^{\bullet}$$

The free radical, $Cl^{\bullet}$ reacts with O_3 through a chain reaction :

$$Cl^{\bullet} + O_3 \longrightarrow ClO^{\bullet} + O_2$$
$$ClO^{\bullet} + O \longrightarrow Cl^{\bullet} + O_2$$

These chlorine atoms are free to react with more ozone. As a result, many O_3 molecules can be destroyed for each chlorine atom produced. It has been shown that over one thousand ozone molecules can be destroyed by one Cl. The net result of these reactions is destruction of several molecules of O_3 for each Cl atom produced.

Thus, *CFCs are transporting agents for continuously producing chlorine radicals into the stratosphere and hence damaging the ozone layer.*

Effects of Depletion of the ozone layer

The **depletion of ozone** layer has the following harmful effects :

(*i*) Depletion of ozone layer poses serious threat to mankind. It results in ageing of skin, cataract, sunburn, skin cancer diseases, etc.

(*ii*) Ultra-violet rays may damage immune system which may lead to increased viral infections.

(*iii*) Increased exposure to ultra-violet radiation will damage marine plants, marine animals and fish which form an important part of human food.

(*iv*) These radiations adversely affect the plant proteins which lead to harmful mutation of cells.

(*v*) These also increase the evaporation of surface water through the stomata of the leaves and decrease the moisture content of the soil.

(*vi*) Increase in ultraviolet radiations damage paints and fibres causing them to fade faster.

(*vii*) Freons trap the warmth of the sun and disturb greenhouse effect leading to higher temperature which could damage crops and pose dangers to low lying ocean port cities from increased melting of ice.

Ozone Depletion over Antarctica

The chain reactions described above can occur all over the stratosphere. However, the depletion of ozone layer leading to **ozone hole** has mainly been observed in the stratosphere over Antarctica. In the other parts of the stratosphere, two alternative reactions consume chlorine monoxide and chlorine atoms as :

$$ClO^{\bullet} + NO_2 \longrightarrow \underset{\text{Chlorine nitrate}}{ClONO_2}$$
$$Cl^{\bullet} + CH_4 \longrightarrow \dot{C}H_3 + HCl$$

In other words, oxides of nitrogen in the stratosphere scavenge the chlorine monoxide radicals while methane molecules scavenge the chlorine radicals. Thus, these destroy the chain mechanism for the ozone depletion and no ozone hole is created.

However, in Antarctica, the conditions are different. During winters, special types of clouds called **Polar Stratospheric Clouds (PSCs)** are formed over Antarctica. These clouds are of two types :

Type I Clouds. These contain some solidified nitric acid trihydrate ($HNO_3.3H_2O$) form at about 196 K.

Type II Clouds. These contain some ice form at about 188 K.

These two types of clouds play a very important role in ozone depletion. On the surface

of polar stratospheric clouds, chlorine nitrate formed in the above reaction undergoes two transformations :

(*i*) It gets hydrolysed as :

$$ClONO_2 + H_2O \xrightarrow{\text{hydrolysis}} HOCl + HNO_3$$

(*ii*) It reacts with hydrogen chloride formed during the reaction

$$ClONO_2 + HCl \longrightarrow Cl_2 + HNO_3$$

These HOCl and Cl_2 formed can be reconverted into reactive chlorine atoms even under mild conditions resulting ozone depletion.

The ozone depletion over Antarctica occurs during spring time (from early September to late October) and gets replenished after spring time. During the spring time, the sun begins to shine over Antarctic skies and HOCl and Cl_2 are photolyzed by sunlight according to the following reactions:

$$HOCl + h\nu \longrightarrow OH^{\bullet} + Cl$$
$$Cl_2 + h\nu \longrightarrow 2Cl^{\bullet}$$

These reactive chlorine atoms formed deplete ozone through the chain mechanism reactions. During winters, when Polar Stratospheric Clouds are formed over Antarctica skies, stable patterns of wind cover the continent. This is called **Polar Vortex** which is a tight whirlpool of winds. This is very rigid so that the air within it is isolated from the sun and from the warmer air of the temperate region. Because of this polar vortex surrounding Antarctica, the ozone rich air from the non-polar region is not able to fill the ozone hole. Therefore, Polar Vortex remains intact during the spring. After the spring, the sunlight increases and the vortex breaks down (some time in November) and the ozone rich air from the temperate region fills the ozone hole.

To control this harmful effects of CFCs, serious efforts are being made to control the use of CFCs and find alternative methods. The **Montreal Protocol** signed by 24 countries in October 1987, was the first step to bring down the world production of freons. At some places, these are being replaced by safe substitutes like hydrochlorofluoro carbons (HClFCS) which have only one tenth as destructive effect as CFCs.

GREENHOUSE EFFECT AND GLOBAL WARMING

Carbon dioxide is an essential component of atmosphere and in normal concentrations, it is harmless. However, due to human activities such as burning of fossil fuels like coal, natural gas, petroleum, etc., the amount of CO_2 entering the atmosphere is increasing. The increase in proportions of CO_2 in atmosphere can lead to global warming through greenhouse effect as explained below:

Sun emits light of different wavelengths consisting of ultra-violet, visible region and infra-red. Of these the harmful ultra-violet radiations are absorbed by the ozone layer in the stratosphere. The visible and infra-red radiation pass through the atmosphere and reach the surface of the earth (Fig. 6). However, some of the light incident on earth is reflected back. For example, of the total incoming light that falls upon the Earth, about 50% reaches the surface and is absorbed by it. About 20% of the incoming light is absorbed by gases in the atmosphere, such as ultra-violet (*uv*) light by ozone in stratosphere and infra-red (IR) by CO_2 and water vapour present in air. The remaining 30% is reflected back into space by particulates and other reflecting bodies without being absorbed.

When the earth cools, the energy is re-emitted from the earth's surface in the form of infra-red radiations which are absorbed by CO_2 and water vapour. After the absorption of infra-red radiations by CO_2 and water vapour, these thermal infra-red radiations are re-emitted in all directions and therefore, some are redirected back towards earth's surface and heat up the atmosphere (earth and air). This heating of the earth due to trapped radiations is called **greenhouse effect**.

Thus, ***the warming of the earth or global warming due to re-emission of sun's energy absorbed by the earth followed by its absorption by carbon dioxide molecules and water vapour present near the earth and then its radiation back to the earth is called greenhouse effect.***

The gases which can trap infra-red radiation given by the sun to produce greenhouse effect leading to heating

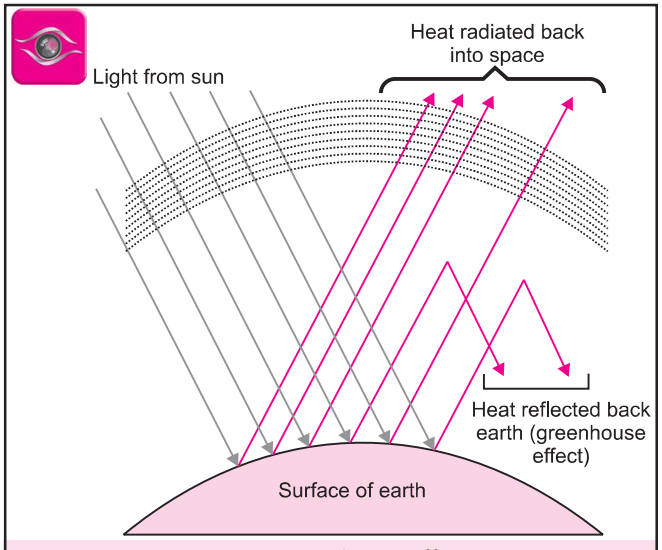


Fig. 6. Greenhouse effect.

up the environment are called **greenhouse gases.** The principal gases of the atmosphere N_2, O_2 and Ar do not absorb infra-red light. The common atmospheric gases that have predominantly produced green house warming are **CO_2, water vapours (H_2O) and ozone (O_3)**. Out of these, water vapours and ozone do not contribute much to the greenhouse effect of the earth's atmosphere because water vapours are found only near the surface of the earth whereas ozone is present only in the upper atmosphere. On the other hand, carbon dioxide is uniformly distributed in the atmosphere and hence makes major contribution towards the greenhouse effect. Thus, **carbon dioxide is regarded as the most important greenhouse gas.**

The other greenhouse gases whose concentration has been small in atmosphere but have ability to warm the air substantially are CH_4, N_2O, $CFCl_3$, CF_2Cl_2, etc. Their concentration in atmosphere is increasing with the industrialization and air pollution.

Greenhouse gases

CO_2, CH_4, O_3, H_2O vapour, CFCs

This phenomenon has been named greenhouse effect because it is similar to a greenhouse for plants that is generally made to protect the plants from cold in winter. In cold places, flowers, fruits and vegetables are grown in glass covered areas called greenhouse. The sun's radiations can enter through the transparent glass and heat up the soil and the plants. The warm soil and plants re-emit infra-red radiations which are partly, trapped by the glass (opaque to infra red radiations) and therefore remain inside the glasshouse. Hence, the glasshouse holds the energy of the sun trapped inside and keeps it warm. Therefore, greenhouse protects the plants from cold climate during winter in cold countries.

Greenhouse Effect in an Automobile

The heating due to greenhouse effect can also be observed inside an automobile such as a car parked in the sun with all its windows closed. The glass windows of the car allow the sun's rays to enter the car. Some of these rays are reflected from the inside surface of the car in the form of infra-red light. These rays are trapped by glass windows (just like CO_2 layer) and cause the interior of the car to heat up. Hence, the inside of the car becomes considerably hot.

Implications of Greenhouse effect or Global Warming

Modern human activities are releasing large quantities of CO_2 in the atmosphere. The increase in its proportion in the atmosphere can lead to global warming through increased greenhouse effect. The CO_2 level in atmosphere was about 290 ppm in 1870. Over the past hundred years we have released about 3,60,000 million tonnes of CO_2 in the atmosphere and are continuing to do so at an increasing rate. Due to this large scale release of CO_2 in the atmosphere, its level in the atmosphere has increased to about 356 ppm.

Methane (a greenhouse gas) is produced naturally when vegetation is burnt, digested or rotten in the absence of oxygen. Large amounts of methane are released in paddy fields, coal mines, from rotting garbage dumps and by fossil fuels.

Chlorofluoro carbons (CFC's) are also responsible for global warming due to their greater efficiency of absorbing thermal infra-red radiations. Each molecule of CFC has the potential to cause the same extent of global warming as do tens of thousands molecules of CO_2. CFC's are being excessively used in insulating freezers, refrigerators and air conditioners and are posing threat of global warming. However, Government is now trying to control the production of CFCs.

The net effect of increased level of all these greenhouse gases is increased greenhouse effect or global warming which may lead to increased global temperature. The global warming will have drastic effect on the climate and may prove disastrous. If nothing is done to control the concentration of these gases into the atmosphere, than average temperature will increase. It has been observed that the average temperature of the earth has increased by about 1°F due to greenhouse effect. If CO_2 is continued to be released into the atmosphere at the present rate then by the end of this century the earth's average temperature is expected to increase by 3.6°F. This excessive heating of the earth would melt all the snow on poles and different mountains. This would increase the water level of the sea and as a result the cities located on the coastal areas are likely to be flooded.

Effects of increase in global temperature on the climate of the earth

The increase in average global temperature can have the following effects on the climate of the earth :

(*a*) In temperate regions, the summer will be longer and hotter and winter will be shorter and warmer. A warmer climate will make certain cities extremely hot to live.

(*b*) There will be increase in total amount of global rainfall but some regions will receive less rainfall.

(*c*) The number of days having intense showers and high temperatures both will increase.

(*d*) The problem of desertification, drought and soil erosion will become more worse.

(*e*) As a result of rise in temperature of the earth, ocean will get warm up and sea level would rise flooding low lying regions. The increase in sea level would have profound effects on habitation patterns and will threaten to submerge many coastal countries like Bangladesh, Indonesia, Maldives, parts of coastal India and many other island nations.

(*f*) Increase in greenhouse effect is expected to cause cooling of the stratosphere. This is because most thermal IR radiations will be absorbed at low altitudes and little will be left to warm stratosphere.

(*g*) Tropical storms, hurricanes, etc. will be stronger and more frequent and will cause devastation.

(*h*) Some areas may become more humid or wetter or some other areas will become dry. The tropics may become wetter and the subtropics which are already dry, are expected to be drier.

(*i*) Due to global warming, human health will be affected. Increased number of hot days and extreme weather may cause chronic respiratory diseases. This also causes increase in the incidences of infectious diseases like dengue, malaria, yellow fever, sleeping sickness, etc.

(*j*) Insect carrying diseases such as malaria may also increase.

(*k*) Animal health will also be affected due to spread of diseases by parasites.

(*l*) Ocean temperature change may also affect marine life adversely.

Methods to prevent global warming

Some steps to minimise the release of green house gases and prevent global warming into the atmosphere are :

(*i*) By minimising the use of cars by car pools or taking public transport in cities. This can also be done by preferring walking or using bicycles.

(*ii*) By planting more and more trees and increasing the green cover.

(*iii*) By avoiding the cutting of trees.

(*iv*) By avoiding the burning of dry leaves, etc.

(*v*) By not smoking in public places and work places.

(*vi*) By educating the public about greenhouse effect and the methods to save our environment.

WATER POLLUTION

Water is most plentiful of all the natural sources. It covers nearly three-fourth of the earth's surface in the form of snow over mountains, as a liquid in the rivers, lakes, springs and oceans. Water is very essential for life. Without water there would be no life. It is very essential for the growth of human body and has significant role in industry, agriculture and civilization.

The quality of water especially for drinking purposes has been a vital factor for the human welfare. The pollution of drinking water has frequently caused many water borne diseases and epidemics such as cholera, typhoid fever, etc. Therefore, water pollution is a matter of serious concern for every citizen. The main culprits for water pollutions are domestic waste from urban and rural areas and industrial wastes which are discharged into natural water supplies.

Water pollution may be defined as

the contamination of water by foreign materials which make it harmful for the health of human beings, animals, plants or aquatic life and make it unfit for domestic, industrial or agricultural uses.

The degree of purity required for water depends upon its use. For example, the water polluted for drinking purposes may be satisfactorily used for irrigation or producing electricity at hydroelectric power plant or for cooling purposes.

Pollution of water originates from human activities. Through different paths, pollution reaches surface or ground water. The easily identified source or place of pollution is called point source *e.g.*, Municipal and industrial discharge pipes where the pollutants enter the water source. On the other hand, non-point sources of pollution are those where a source of pollution cannot be easily identified. For example, acid rain, storm water drainage (from streets, parking lots, lawns etc.) agricultural runs off (from farm, animals and crop lands etc.). The major water pollutants and their common sources are given in Table 2.

Table 2. Major Water Pollutants and their Sources.

Pollutant	Sources
Micro-organisms	Domestic sewage
Organic wastes	Domestic sewage, animal manures, food processing wastes, decaying plants and animals, paper discards, rags and other bio degradable wastes
Plant nutrients	Chemical fertilizers
Toxic heavy metals	Industries and chemical factories
Sediments	Insoluble particles of soil and rock and inorganic and organic compounds which wash into water from mining, agricultural activities, construction activities and soil erosion.
Pesticides	Chemicals used for killing insects, fungi and weeds
Radioactive wastes	Mining of uranium containing minerals and accidental release from nuclear plants.
Heat	Water used by industrial plants for cooling which is discharged as hot water.

SOURCES OF WATER POLLUTION

The water pollution may be caused by domestic sewage, industrial effluents, agricultural discharges, sedimentation, radioactive discharges, thermal pollutants etc. The major sources of water pollution are domestic sewage and industrial wastes.

(*i*) Domestic sewage. The domestic sewage contains oils, human excreta, dirt, paper, rags, sand grains, dissolved material such as detergents and inorganic compounds such as sodium chloride, ammonium sulphate and ammonium phosphate, decomposed kitchen waste. The sewage also contains many disease causing bacterias called **pathogens which are most serious water pollutants**.

(*ii*) Industrial wastes. Industrial wastes are also the major source of water pollution. The industrial wastes polluting water are mainly from industries such as coal or ore mines, textile industries, paper industries, food processing industries, dairies, chemical industries, pharma-ceuticals, sugar and distilleries, oil refineries, tanneries, vegetable oil and soap industries etc. These wastes may contain inorganic and organic suspended particles and inorganic and organic soluble matter.

(*iii*) Agricultural discharges. These include fertilizers, pesticides and insecticides, etc. entering the water body.

(*iv*) Sediments. Water can also be polluted by sediments. These are water insoluble particles of soil and rock and many inorganic and organic compounds which wash into water from mining, agricultural activities, construction activities and activities associated with soil erosion. It represents the most extensive pollutants of surface water.

(*v*) Radioactive pollutants. Many radioactive isotopes enter the surface water from geothermal wells or accidental releases from nuclear power plants.

(*vi*) Thermal pollutants. Many processes such as combustion of fuel in boilers, electric power plants and industrial plants produce a lot of heat. Therefore, to cool the various equipments, the water from the nearby rivers, lakes and ocean bays are circulated through the heated parts. The circulating water becomes hot and when this hot water is discharged back to the surface water, it can have many adverse effects. This is called **thermal pollution**.

(*vii*) Oil. Water pollution in seas and rivers is caused by oil due to increased use of oil base technology, excessive off-shore explorations and transportation of oil through water ways. This results from discharge of oil from oil tankers and offshore drilling explorations and accidents, leakage of pipe lines over and under water ways.

TYPES OF WATER POLLUTANTS

1. Pathogens. The most serious water pollutants are the disease causing agents called pathogens.

Pathogens include bacteria and other organisms which enter water from domestic sewage and animal excreta. Human excreta contains bacteria such as **escherichia coli** and **streptococcus faecalis** which cause gastrointestinal diseases. These bacteria can cause great epidemic diseases.

2. Organic wastes. The organic matter such as leaves, grass, trash etc. are also common pollutants. These pollute water as a consequence of run off. Excessive phytoplankton growth within water is also a cause of water pollution. These wastes are biodegradable. The large population of bacteria decompose organic matter present in water.

3. Chemical pollutants. Water being an excellent solvent dissolves many water soluble inorganic chemicals. Some of these pollutants are:

(*i*) Heavy metals. These are metals such as cadmium, lead and mercury which are present in industrial or mining wastes. These metals are poisonous and can be dangerous to humans because our body cannot excrete them. These metals can cause damage to kidneys, liver, central nervous system, etc. For example, cadmium and mercury can cause kidney damage whereas lead poisoning can cause damage to the kidneys, liver, intestines, brain and central nervous system. Mercury poisoning causes a disease called **minamata** in human beings which weakens the muscles and results in weakness in hearing and vision power, mental retardation and paralysis. All of these metals are **cumulative poisons** because the body does not excrete them and their concentration builds up.

(*ii*) Detergents and fertilizers. These may contain phosphates as additives. It may be noted that these do not pose any threat to the aquatic life but serve as nutrients for plants leading to their excessive growth in ponds, lakes and rivers. These encourages the formation of algae which reduces the dissolved oxygen concentration of water. This process of overnutrition is known as **eutrophication.** This impedes the development of higher life forms such as fish.

(*iii*) Petroleum products. Petroleum products also pollute many sources of water. *e.g*., major oil spills in ocean. This is because of wreckage of oil tankers in open sea or accidents of ships carrying oil in the sea. The spreading of oil into sea is called **oil spill** and the thick layer of oil on the surface of sea water is called **oil slick**. In India an oil spill occurred in Bombay on March 17, 1993 due to rupture of pipeline which damaged the ecosystem and marine life.

(*iv*) Acid polluted water. The acid polluted water having pH less than 3 is deadly to most forms of aquatic life. The water downstream from a mine may

get contaminated by acid mine drainge formed by microbial oxidation of discarded waste materials at the nine site. The acid mine water mainly contains sulphuric acid produced by the oxidation of iron pyrites (FeS_2). Industrial wastes and acid rain also contribute to the acidic nature of natural water.

(*v*) Polychlorinated biphenyls (PCBs). Polychlorinated biphenyls have very high stabilities and therefore, are finding many applications these days. For example, these are used as fluids in transformers and capacitors, as cleansing solvents, detergents and fertilizers. PCBs are resistant to oxidation and their release into the environment has become a serious pollutant. These are carcinogenic and cause skin disorders in humans. Now a days most of the detergents available are biodegradable. But their use can create other problems. The bacteria responsible for their degradation feed on degradable detergent and grow very rapidly. During their growth, the bacteria may take all the oxygen dissolved in water. As a result of lack of oxygen, other forms of aquatic life such as fish and plants may die. Fertilizers, as we know contain phosphates as additives. The addition of phosphorus in water promotes algae growth. Such a large growth of algae may `cover the water surface. These algae growth often release toxins in water. This bloom infested water will inhibit the growth of other living organisms in the water body. The process of nutrient enrichment of water bodies and subsequent loss of biodiversity is called **eutrophication**.

Until recently, it was a common practice to dump the industrial wastes into nearby stream. These days, this practice has been stopped to prevent stream pollution and to recover some expensive chemicals from these wastes. However, it may be noted that the treatment of industrial wastes is very tedious problem because of the large variety of chemicals present in black liquor coming from the industries.

The treatment of industrial wastes depend upon the nature of the pollutants present.

IMPORTANCE OF DISSOLVED OXYGEN IN WATER

The concentration of dissolved oxygen (DO) in water is very important to support the aquatic life. If the concentration of dissolved oxygen becomes low, the water is said to be polluted. The lower the concentration of dissolved oxygen, the more polluted is the water sample. If the dissolved concentration of oxygen in water is below 6 ppm, the fish growth is inhibited. The two main sources of oxygen are : the oxygen dissolves at the surface of the water from the atmosphere and from photosynthesis carried by many aquatic green plants during day light. It may be noted that still water takes up oxygen slowly whereas turbulent water takes it up more rapidly because bubbles are commonly sumerged. Moreover, at the places where there are many aquatic green plants, the water becomes supersaturated with oxygen during the hours of daylight due to photosynthesis. However, after dark, photosynthesis stops but the plants continue to respire and therefore, the amount of dissolved oxygen decreases. Consequently, during a period of 24 hours, some water samples have considerable amount of dissolved oxygen.

The deoxygenation of water is carried out by various processes. For example, the dissolved oxygen in water is consumed rapidly by micro-organisms to oxidise organic matter of sewage.

$$\underset{\text{From organic matter}}{[CH_2O]\,(aq)} + O_2\,(aq) \xrightarrow{\text{Micro-organisms}} CO_2\,(aq) + H_2O(l)$$

If the concentration of the dissolved oxygen is not restored either by the turbulent flow of shallow water or by a reaction, it is not able to support many organisms. The dissolved oxygen in water is also consumed by the biooxidation of the nitrogenous material.

$$NH_4^+\,(aq) + 2O_2\,(aq) \longrightarrow 2H^+\,(aq) + NO_3^-\,(aq) + H_2O(l)$$

and by the chemical or biochemical oxidation of chemical reducing agents.

$$4Fe^{2+}\,(aq) + O_2\,(aq) + 10\,H_2O\,(l) \longrightarrow 4Fe(OH)_3\,(s) + 8\,H^+\,(aq)$$

$$2SO_3^{2-}\,(aq) + O_2\,(aq) \longrightarrow 2SO_4^{2-}\,(aq)$$

Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

The organic waste can be broken down by both aerobic and anaerobic bacteria which act under different conditions. **Aerobic bacteria** are oxygen consuming decomposers which bring about the oxidation of degradable organic matter into carbon dioxide, nitrates, sulphates, phosphates, etc. As a result of aerobic oxidation, dissolved oxygen in the water decreases. Due to short supply of oxygen, the aquatic organisms especially fish and shell fish die from suffocation. Complete oxygen removal kills many other forms of aquatic life except anaerobic bacteria which do not require oxygen.

On the other hand, **anaerobic bacteria** do not require oxygen for the decomposition of organic wastes. The decomposition of organic waste by anaerobic bacteria produce toxic and foul smelling substances such as hydrogen sulphide, ammonia, methane, phosphine, ammonium sulphide, etc. This kind of oxidation of sewage is called anaerobic oxidation.

Dissolved oxygen is an essential requirement of aquatic life *i.e.* animal and plant population in water. The quantity of oxygen consuming wastes in water is usually determined by measuring the **biological oxygen demand** (B.O.D). It is defined as the

amount of oxygen required by microorganisms (bacteria) to break down the organic matter present in a certain volume of a sample of water.

The amount of BOD in water is a measure of the amount of organic material in water, in terms of how much oxygen will be required to break it down biologically.

The carbon of organic matter is converted into CO_2 and since 1 mol of C requires 1 mol of oxygen, BOD is directly related to the concentration of organic matter. Therefore, the high value of BOD. indicates that water is polluted. Therefore, the BOD is taken as a realistic measure of water quality. **The clean water would have a BOD value of less than 5 ppm whereas BOD of 17 ppm or more indicate highly polluted water.**

In order to measure BOD, the water sample is first saturated with oxygen. It is then incubated at constant temperature (usually 20°C) for 5 days. This allows time for micro-organisms in water sample to oxidise organic matter. The remaining oxygen is determined and the difference gives the amount of oxygen consumed by micro-organisms for decomposition i.e., BOD.

There is another parameter called **chemical oxygen demand** (COD). Certain chemicals other than organic wastes also react with dissolved oxygen in water. This is referred as **chemical oxygen demand (COD).** Thus, BOD measures the oxygen consumed by living organisms assimilating organic matter present in waste while COD is a measure of biological oxidisable as well as biological inert organic matter such as cellulose. Thus, if BOD or COD values of water are large, it indicates that water is heavily polluted.

In order to measure COD, the given water sample is treated with a known quantity of an oxidising agent (potassium dichromate, $K_2Cr_2O_7$) in acidic medium. This oxidises most of the polluting substances including those which are resistant to microbial oxidation. The excess of $K_2Cr_2O_7$ is determined by back titration with a suitable reducing agent such as Mohr's salt. From the concentration of $K_2Cr_2O_7$ consumed, the amount of oxygen used in oxidation may be calculated using the following chemical equation :

$$K_2Cr_2O_7\ (aq) + 4H_2SO_4\ (aq) \longrightarrow K_2SO_4\ (aq) + Cr_2\ (SO_4)_3\ (aq) + 4H_2O\ (l) + 3O\ (aq)$$

The results are expressed in terms of amount of oxygen in ppm that would be required to oxidise the contaminants. This is called COD.

WATER QUALITY PARAMETERS AND INTERNATIONAL STANDARDS

The quality of water is of vital concern for mankind because it is directly linked with human welfare. The main requirements for drinking water are :

The drinking water should be fit for human consumption having the following essential parameters for water quality :

(*i*) It should be colourless and odourless.

(*ii*) It should be pleasant in taste.

Table 3. Permissible Limits of Drinking Water.

Parameter	Permissible limits (ppm)	Ill-effects of pollutants
Dissolved Oxygen	250	—
(pH)	5.5–9.5	
Arsenic	0.05	Cramps, paralysis
Barium	1.0	Toxic to heart
Cadmium	0.005	Anaemic, kidney dysfunction
Chromium	0.05	Carcinogenic
Fluoride	1–1.5	Skeleton disorder, nervous breakdown and mottling of teeth enamel
Lead	0.05	Anaemic, kidney dysfunction, nervous
Aluminium	0.2	disorder, brain damage
Selenium	0.01	Toxic at high levels
Copper	3.0	Toxic to plants and algae
Mercury	0.001	Highly toxic, mental disorders and death
Zinc	5.0	Toxic
Alkyl benzene-sulphonate	0.5	Irritation of the gastrointestinal tract
Chloride	600	Harms agricultural crops
Sulphate	500	Laxative and hypertension
Pesticides	0.005	Toxic, carcinogenic, kidney dysfunction

(*iii*) It should be clear and turbidity should be less 10 ppm.

(*iv*) Its pH should be between 5.5 to 9.5.

(*v*) The total dissolved solids should not be more than 500 ppm.

(*vi*) It should be free from disease causing micro-organisms.

(*vii*) It should be reasonably soft.

(*viii*) It should be free from objectionable chemicals.

There are some international standards for drinking water which must always be obeyed if water is to be used for drinking purposes. The parameters and standards for water quality and harmful effects of pollutants beyond permissible limits are given in Table 3 for some common chemicals. Some of these are also briefly discussed below :

1. Fluoride. Soluble fluoride is normally added to drinking water and its concentration should be upto 1–1.5 ppm or 1–1.5 mg dm^{-3}. This limit is within agreed safety limits and protects teeth against decay. The deficiency for this compound in drinking water is harmpul to man and causes diseases such as tooth decay, etc. The F^- ions make the enamel on teeth much harder, by converting hydroxyapatite $[3Ca_3(PO_4)_2 . Ca(OH)_2]$ the enamel on the surface of the teeth into harder fluorapatite $[(3Ca_3 (PO_4)_2. CaF_2]$. However, F^- ion concentration above 2ppm causes brown mottling of teeth. Higher concentrations of fluoride are poisonous and are harmful to teeth and bones at levels above 10 ppm (mg dm^{-3}). This problem has been reported from some parts of Rajasthan.

2. pH. The pH of the drinking water should be between 5.5 to 9.5. A decrease in pH of the water increases the solubility of the heavy metal ions.

3. Sulphate. Sulphate is harmless at moderate concentrations but excessive concentration of sulphate above 500 pm produces laxative effects and hypertension.

4. Nitrate. Excessive nitrate in drinking water is also harmful and can cause ***methemoglobinemia*** (blue baby syndrome). It is linked to stomach cancer. The maximum limit of nitrate ion in drining water is 50 ppm.

5. Lead. Lead pipes are very commonly used for water transport and is liable to get contaminated with lead, particularly when water is acidic. The permissible limit for lead ions in drinking water is 50 ppb (µg dm^{-3}). Excessive lead cause anaemia, kidney dysfunction, nervous disorder, brain damage etc.

6. Other metals. The maximum permissible limit recommended of common metals in drinking water and their ill effects are given alongside.

Table 4. Maximum prescribed concentration of some metals in drinking water.

Metal	Maximum Concentration (ppm or mg dm^{-3})
Iron, Fe	0.2
Manganese, Mn	0.05
Aluminium, Al	0.2
Copper, Cu	3.0
Zinc, Zn	5.0
Cadmium, Cd	0.005

R.U. Curious...

❑ **Certain newly born babies develop illness known as blue baby syndrome.**

▶ Blue baby syndrome or simply known as blue baby is a term used to describe the infants with blue tinted skin. This may be caused by excessive nitrate (NO_3^-) ions in drinking water in some rural area having high levels of nitrates present in ground water. When consumed, the nitrates get reduced to nitrite ions in the digestive system. The nitrites react with oxyhemoglobin (the oxygen carrying blood protein) to form methemoglobin, which cannot carry oxygen. As a result, the oxygen carrying capacity of blood gets reduced and the organs, cells, tissues or skin may be deprived of oxygen, causing infants to develop blue baby syndrome. This can be fatal if left untreated leading to even death. This condition is also known as **methemoglobinemia**.

SOIL POLLUTION OR LAND POLLUTION

Soil receives large quantities of hazardous wastes from different sources and gets polluted.

Any factor which deteriorates the quality, texture and mineral content of the soil and disturbs the biological balance of the organisms in it and has lethal effect on the plant growth is called **soil pollutant.**

India being agricultural based economy gives high priority to agriculture. The production of agriculture depends primarily on the quality of soil because it is the soil which provides nutrients, water and minerals for the growth of plants. However, India is also facing serious problem of deteriorating quality of soil and resulting into soil pollution. The main sources of soil pollution are dumping of industrial wastes, urban wastes, volatile organic compounds, radio-active wastes and agricultural practices. Among these modern agricultural practices pollute the soil to a large extent. With the increasing use of fertilizers, pesticides, herbicides, weedicides and soil conditioning agents to increase the crop yield, the soil pollution problems have also been increased.

Fertilizers contaminate the soil with impurities which come from raw materials during their

manufactures. For example, As, Pb and Cd present in rock phosphate mineral get transferred to superphosphate fertilizers. Since the metals are not degradable, these get accumulated in the soil due to the excessive use of phosphate fertilizers. Similarly, some metal ions such as Co^{2+}, Zn^{2+}, Ni^{2+}, Mn^{2+} etc. are added to the soil in trace amounts as micronutrients. However, excessive addition of these micronutrients may lead to their accumulation above the toxic level. These may also cause soil pollution.

Different kinds of pesticides are used to control pests in the crops. Though these pesticides help in getting boost in food production, yet the excessive use has been of great concern because these cause soil pollution. These pose a potential danger to the human health because eating of food contaminated with these chemicals may cause serious problems. Consequently, many of these chemicals have been banned or restricted in use.

Thus, the role of pesticides in protecting crops and generating pollution is very significant and discussed below :

Role of Pesticides in generating Pollution

The chemicals which are used for destroying pests are called **pesticides.** These are used to kill or control unwanted dangerous species of plants and animals. Pesticides are basically synthetic toxic chemicals with ecological repercussions. The repeated use of the same or similar pesticides make some pests resistant to that group of pesticides, thereby, making the pesticides uneffective. For example, when insect resistance of DDT increased, other organic toxins such as Aldrin and Dieldrin, etc. were introduced. Most of the organic toxins are water insoluble and non-biodegradable. Therefore, these high persistent toxins are transferred from lower trophic level to higher trophic level through food chain. Over the time, the concentration of toxins in higher animals reach a level which causes serious metabolic and physiological disorders. In response to high persistence of chlorinated organic toxins, a new series of less persistent or more biodegradable products have been introduced. These are **organo-phosphates** and **carbamates**. But these chemicals are severe nerve toxins and hence are more harmful to human beings. There are some reports of pesticides related deaths of agricultural field workers.

The pesticides may be classified in following categories:

1. Insecticides

These are used to kill insects in agricultural fields. During world war II, DDT [2,2 (bis-p-chlorophenyl)-1,1,1- trichloroethane] was found to be of great use in controlling malaria and other insect borne diseases. Therefore, after the war, DDT was used in agriculture to control the damages caused by in sects, rodents, weeds and various crop diseases. Other common examples of insecticides are : malathion, carbaryl, BHC. Among these DDT (dichloro diphenyl trichloro ethane) is an organo chlorine compound. Organo chlorine compounds are stable in the environment, toxic to insects in small amounts but much less so to humans, because they are not very soluble in water. These are persistent and show their biological activity for long periods of time. However, these insecticides by accumulating in the environment affect many non target organisms in addition to the target pests.

2. Herbicides

These are used to kill weeds or undesirable vegetations. For example : sodium chlorate ($NaClO_3$), sodium arsenate ($NaAsO_3$),2,4 dichlorophenoxy acid, triazines, etc. Most herbicides are toxic to mammals but are not as persistent as organo-chlorides. These chemicals decompose in a few months. Like organo-chlorides, these also become concentrated in the food web. Same herbicides cause birth defects.

3. Fungicides

These are used to control the growth of various types of fungus and check plant diseases. For example, thiram $(CH_3)_2$ NCSS, phenyl mercury acetate, bordeaux mixture. Generally, organic compounds of mercury have been used as fungicides. However, these compounds break down in soil and these have disastrous consequences. In Iraq many deaths were reported in 1971-72 resulted from the people eating bread made from grain that had been treated by fungicide methyl mercury.

4. Rodenticides

These are used to kill rodents (rats and mice). For example : warfarin, zinc phosphate.

In addition pesticides also include *nematicides* (which inhibit nematodes), *molluscicides* used to kill molluscs mainly snails and slugs), *piscicides* (used to control undesirable fish species and other aquatic animals).

A major Air Pollution Accident—Bhopal Gas Tragedy

A major air pollution accident took place on the night of December 2, 1984 in Bhopal (Madhya Pradesh in the Union Carbide Factory. This is known as **Bhopal gas tragedy**. On the chilly night, when the city of Bhopal was virtually asleep, at about 11.30 pm a dense cloud of deadly methyl isocyanate (MIC) gas leaked from a storage tank of Union Carbide Ltd. plant. This caused intense aching in the eyes of people around the factory. This resulted into deaths of thousands of people and many suffered permanent medical disability. Many women were badly affected and the worst victims being pregnant women.

Methyl isocyanate (MIC) was used to manufacture the insecticide, carbaryl marked under the commercial name **sevin** in this plant. It was prepared by the reaction of methylamine and phosgene.

$$\underset{\text{Phosgene}}{CH_3NH_2 + COCl_2} \longrightarrow \underset{\text{MIC}}{CH_3N = C = O} + 2HCl$$

MIC is stored in refrigerated moisture free tanks in Union Carbide Factory. It is very sensitive to moisture and itself is a volatile liquid (b.p. 43.45°C). It has been investigated that probably pressure rose in one of the tanks and opened its release value thereby allowing methyl isocyanate to escape into the atmosphere. As the clouds of methyl isocyanate rose over the city, it caused immense loss of life and injury to people. It proved to be a big tragedy.

Monitoring and Control of Pesticide Pollution

Excessive use of pesticides pose a potential hazard to man, animal, fish, vegetations, etc. These spread most widely and alarming danger to the environment. The use of many toxic pesticides have been banned. India is one of the few producers of DDT in the world, which has been banned by USA since 1972 for environmental reasons.

STRATEGIES TO CONTROL ENVIRONMENTAL POLLUTION

To protect human life and lives of plants and other animals, scientists are working hard to plan certain strategies for control of environmental pollution. In addition to solid waste which we see in our household garbage bins, there are medical, industrial, agricultural and mining wastes. The improper disposal of wastes is one of the major causes of environmental pollution. Therefore, the management of wastes is of prime importance. Let us briefly study the methods to control other types of pollution caused by different sources. This involves two common strategies :

A : Management of waste

B : Green chemistry.

A. MANAGEMENT OF WASTE

The production and improper disposal of domestic and industrial wastes are responsible for environmental pollution. The domestic waste includes sewage and municipal waste while industrial wastes include inorganic and organic suspended particles and inorganic and organic soluble matter.

Management of Industrial Waste.

Most industries produce one or more unwanted by products which must be discarded. The problem of solid waste disposal is one of the most serious problem facing our society today.

Industrial solid wastes are sorted out as biodegradable and non-biodegradable wastes.

Biodegradable wastes are generated by food processing units, cotton mills, paper mills and textile factories.

Non-biodegradable wastes are generated by many industrial processes such as:

(*i*) thermal plants produce fly ash

(*ii*) iron and steel plants produce blast furnace slag and steel melting slag.

(*iii*) industries manufacturing aluminium, zinc, copper, etc, produce mud and tailings.

(*iv*) fertilizer industries produe gypsum.

(*v*) industries dealing with metals, chemicals, drugs, pharmaceuticals, dyes, rubber, goods, etc. produce hazardous wastes such as inflammables, composite explosives or highly reactive species.

The disposal of non-biodegradable industrial solid wastes, is very essential. If it is not done by a proper and suitable method it may cause serious threat to the environment. New innovative methods have been designed to make use of waste materials. Great care has to be taken for the disposal of toxic wastes. For example, nowadays, fly ash and slag from the steel industry are used in the cement industry. Large amounts of toxic and hazardous wastes are destroyed by controlled incineration whereas small quantities are burnt along with factory garbage in open bins. Moreover, solid wastes if not managed effectively will affect the components of environment.

Management of Domestic waste.

The best way to manage domestic wastes are to collect these in small bins which are transferred to community bins by private or municipal workers. From these community bins, the wastes are collected and carried to disposable sites. At these sites the wastes are separated into biodegradable and non-biodegradable wastes. Non-biodegradable waste meterials such as glass, plastic, metal scraps, etc. are sent for recycling whereas biodegradable wastes are dumped in land fills and are converted into compost.

If the waste is not collected in garbage bins, it goes into the sewers. Some of it is eaten by dogs and cattles. Non-biodegradable wastes (polythene bags, metals scraps etc.) choke the sewers and cause inconvenience and problems. Polythene bags, if swallowed by cattle can cause their death also. The poor management of waste causes health problems leading to epidemics due to contamination of ground water. It is specially dangerous for those who are in direct contact with the waste such as rag pickers and workers involved in waste disposal because these persons handle waste materials mostly without protective devices such as gloves or water proof boots and gas masks. **We are responsible for their lives.**

Therefore, the normal practice is that all the domestic wastes should be properly collected and

disposed. These wastes are treated in the following ways :

1. Recycling

This is a simplest method in which the waste is recycled. When the materials are recycled, it saves on the cost of raw materials as well as reduces the costs of waste disposals. Some common examples of recycling by industries are :

(*i*) the collection and recycling of glass

(*ii*) the use of scrap metal in the manufacture of steel

(*iii*) recovery of energy from burning combustible waste.

(*iv*) the use of waste paper

In other words, *recycling converts waste into wealth.*

2. Sewage treatment

The sewage treatment involves the following three types of stages :

1. The **first stage** known as **primary treatment** involves the removal of large solid particles. This is done by mechanical process consisting of **screening** and **sedimentation.** For this, the waste is filtered through different types of screens. The solids that are removed are disposed off in land fill sites. It is then allowed to flow into sedimentation tanks. This process allows the removal of solids that settle out (called **sludge).** This process also allows the removal of grease which floats to the surface and can be skimmed off.

2. The **second stage** known as **secondary treatment** involves the biological oxidation of organic content of waste materials by micro-organisms followed by filtration.

3. The **third stage** also known as final treatment is a series of specialized physical and chemical processes that reduce the quantities of specific pollutants left after primary and secondary treatments. These improve the quality of waste water. The processes commonly used in this treatment ore chemical removal of phosphate, coagulation, filtration, treatment with activated charcoal, disinfection by chlorine, reverse osmosis, etc.

During these operations sludge is produced which also poses a problem for safe disposal. The sludge is dried and then may be incinerated, digested or damped as explained below :

***(a)* Incineration**

This converts organic materials into CO_2 and water. This is used for household waste, chemical waste and biological waste (e.g. from hospitals). Such treatment is carried out under aerobic conditions in the presence of plentiful supply of oxygen and at very high temperature (above 1273 K). The exhaust gases are filtered. This process reduces the volume of the waste and inorganic ash is left behind which is disposed of as land fill.

$$\text{Organic waste} + O_2 \xrightarrow[> 1273\ K]{\text{Aerobic conditions}} CO_2 + H_2O$$

This method disposes of the relatively inert PCBs (polychlorobenzenes) and the high temperature generated allows the endothermic reactions such as destruction of C–Cl bonds in organochlorine compounds. The main disadvantage of this process is that it causes air pollution. Moreover, the ash from the municipal incinerators is very finely divided and can be ingested into the lungs. Incomplete combustion of PCBs can cause formation of highly toxic chloro compounds such as polychlorodibenzodioxins (PCDDs) and polychlorodibenzofurans (PCDFs).

***(b)* Digestion**

The sewage sludge can undergo anaerobic digestion when micro-organisms degrade wastes in the absence of oxygen. This process can also be used to degrade a variety of toxic organic wastes. The products of digestion are carbon dioxide and methane, which may be used as a fuel.

$$2\begin{bmatrix}\text{Organic waste}\\ \text{C, H, O}\end{bmatrix} \longrightarrow CO_2\,(g) + CH_4\,(g)$$

(*c*) Dumping

This is widely used practice of dumping the sewage sludge in the nearby seas. It is known as ocean dumping. However, the application of sludge to the land is increasing. The sludge contains nitrogen and phosphorus which may be useful as a fertilizer. Urban areas produce sludge which contains many toxic substances, so the amount of such sludge dumped in this way must be carefully controlled.

B. GREEN CHEMISTRY AS AN ALTERNATIVE TOOL FOR REDUCING AIR POLLUTION

We have learnt that increasing population, increased use of fossil fuels and increasing number of industries and vehicles are polluting our environment to an alarming extent. The increase in pollution adversely affects the health of humans and other living organisms. As we know self sufficiency in food has been achieved in India since late 20th century by using fertilizers and pesticides and developing improved methods of farming, good quality of seeds, irrigation etc. But over exploitation of soil and excessive use of fertilizers and pesticides have resulted into deterioration of soil, water and air.

With the growing awareness of the environmental pollution, the international community is under increasing pressure to find methods to save our lives from the increasing pollution. This does not mean that we should stop the process of advancement that has been set in but to search methods which would help in reduction of pollution of our environment. The scientists are searching new alternatives which do not cause environmental pollution. This new approach is

called **Green Chemistry** which was introduced in early 1990s**.** It means zero discharge of toxic, persistent substances, into the environment guaranted by the fact that they are never produced. **Green chemistry** may be defined as

a strategy to design chemical processes and products that reduces or eliminates the use and generation of hazardous substances.

This would bring about minimum pollution or deterioration to the environment. In other words, green chemistry aims to virtually eliminate toxic, persistent substances from the environment by ensuring their no further releases and destroying existing deposits of these chemicals. So, green chemistry means environmental friendly or no pollution. For example, we have been using organic solvents such as benzene, toluene, carbon tetra-chloride, etc. as a media for many reactions. These are highly toxic. Now, scientists are planning greener alternative to use water or non polluting solvents as a medium in place of organic solvents. Similarly, instead of using synthetic materials for packing, green chemistry plans to use environmental friendly recyclable or safely disposable materials.

Green chemistry also requires change in our habits and life-style. These days many green products are available in the market in developed countries.

BASIC AIMS OF GREEN CHEMISTRY

Since the inception of green chemistry, scientists from all over the world are using the creative and innovative skills to develop new synthetic methods, new processes, analytical tools, reaction conditions, catalysts, etc. **So, green chemistry prevents problems before they occur by designing new approaches.** Green chemistry considers the full life cycle impacts of a product at the initial design stage. The **basic aims** of green chemistry are :

(*i*) Reformulation of synthetic routes so that hazardous substances do not enter into the atmosphere.

(*ii*) During synthesis, care must be taken to select starting materials that can be converted into end products with allmost 100% yield. This can be achieved by arriving at optimum conditions of synthesis.

(*iii*) The methods used to obtain starting materials *e.g.* mining, refining, etc. should have minimum impact on the natural environment.

(*iv*) New routes for the production of green chemicals and materials.

(*v*) The development of environmentally improved methods for the existing industrial processes. The material inputs should be of low or no toxicity or at least reduced toxicity compared with the traditional method.

(*vi*) The use of starting materials–reagents and solvents that pose less hazard to man and his environment.

(*vii*) The synthetic reactions may preferably be carried out in aqueous medium because water has high specific heat and low volatility. Water is cost effective, non-inflammable and does not have any carcinogenic effects.

(*viii*) The raw materials and methods should produce less waste to avoid their treatment and problem of disposal.

(*ix*) The use of renewable rather than depleting resources wherever possible.

(*x*) The use of biotechnological alternatives.

(*xi*) New methods and tools for evaluating environmental impact.

(*xii*) The awareness among common man to use green products.

Green chemistry in Day-to-Day Life

Some common examples of green chemistry in our day-to-day life are:

(*i*) Dry cleaning of clothes.

Tetrachloroethene ($Cl_2C = CCl_2$) has earlier used as solvent for dry cleaning. This compound is suspected to be carcinogenic and contaminates the ground water. The process of using this compound has now been replaced by a new process in which liquefied carbon dioxide alongwith suitable detergent is used. This causes less harm to ground water. Replacement of halogenated solvent by liquid CO_2 will result in less harm to ground water.

Similarly, hydrogen peroxide (H_2O_2) is used for the purpose of bleaching clothes in the process of laundry. This gives better results and makes use of less water, therefore, saving a lot of water. It is also not harmful.

(*ii*) Bleaching of paper

Chlorine gas was used earlier for bleaching paper, which is highly toxic chemical. Its use has been replaced by hydrogen peroxide with a suitable catalyst which promotes the bleaching action of hydrogen peroxide.

(*iii*) Synthesis of chemicals.

Ethanal (CH_3CHO) is commercially prepared nowadays by one step oxidation of ethene in the presence of ionic catalyst in aqueous medium:

$$\underset{\text{Ethene}}{CH_2=CH_2} + O_2 \xrightarrow[\text{in water}]{\text{Catalyst Pd(II),Cu(II)}} \underset{\text{Etanal}}{CH_3CHO}(90\%)$$

The yield is about 90.0%.

Thus, we can say that green chemistry is a cost effective approach which involves reduction in material, energy consumption and waste generation.

Always remember environment protection begins with us.

To save our environment, we all as human beings have to think seriously. If we follow some basic steps as an individual to keep our environment pollution free, we can contribute significantly towards a better quality of our environment and human life.

* Always set up a compost pit in your garden or any other place in your home and use it to produce manure for your plants. This will reduce the use of fertilizers.
* Always use a cloth bag instead of plastic carry bags when you buy vegetables, fruits, groceries or any other item.
* Take care that all newspapers, glass, aluminium and other items in your area are recycled.
* We must realize that though we donot have solutions for every problem but we can concentrate on issues and try to find their proper solutions.
* We should always take care to put into practice whatever we preach.

Always remember, environmetal protection begins with us.

add on Conceptual Questions

CONCEPTUAL QA

Q.1. Explain giving reasons "the presence of CO reduces the amount of the haemoglobin available in the blood for carrying oxygen to the body cells".

Ans. CO is a poisonous gas and it binds to haemoglobin of the blood more readily (about 200 times) than oxygen to form carboxy haemoglobin.

$$Hb + CO \rightleftharpoons HbCO$$

Carboxy haemoglobin

The presence of CO, therefore, reduces the amount of the haemoglobin available in the blood for the transport of oxygen to the body cells.

Q.2. Fish do not always grow as well in warm water as in cold water. Why ?

Ans. The amount of dissolved oxygen in warm water is less than in cold water.

Q.3. Name four major Greenhouse gases.

Ans. (*i*) Carbon dioxide (*ii*) Methane (*iii*) Ozone (*iv*) Chlorofluorocarbon compounds.

Q.4. Why is acid rain considered as a threat to Taj Mahal ?

Ans. Taj Mahal is made of marble. The acid rain contains H_2SO_4 which attacks the marble ($CaCO_3$):

$$CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + H_2O + CO_2$$

As a result, the marble becomes pitted and weakened mechanically. Therefore, the monument is being slowly eaten away and the marble is getting discoloured and lustreless.

Q.5. Why does the rain water normally have a pH of about 5.6 ? When does it become acid rain ?

Ans. Normally rain water has a pH of about 5.6 due to the dissolution of CO_2 of the atmosphere into it :

$$H_2O(l) + CO_2(g) \longrightarrow H_2CO_3$$

$$H_2CO_3 \longrightarrow 2H^+ + CO_3^{2-}$$

When the pH of rain water falls below 5.6, it becomes acid rain.

Q.6. What is pneumoconiosis ? How does it occur ?

Ans. Pneumoconiosis is a disease of lung which is caused due to inhalation of small particles (mist, smoke, fumes and dust). These particles irritate the lungs and exposure of such particles for long periods of time causes scarring or fibrosis of the lung lining.

Q.7. Name the gas which caused Bhopal Gas Tragedy.

Ans. Methyl isocyanate (CH_3 N = C = O) or MIC.

Q.8. Name four tropospheric pollutants.

Ans. The tropospheric pollutants may be gaseous or particulate. For example,

Gaseous : Oxides of sulphur, Oxides of nitrogen

Particulate : Dust, Smoke.

Q.9. What is the major cause of ozone layer destruction ?

Ans. The major cause of ozone layer destruction is the release of chlorofluorocarbon compounds (CFCs) know as freons in the atmosphere.

Q.10. List main differences between classical smog and photochemical smog.

Ans. The main difference between classical smog and photochemical smog are :

Classical smog	Photochemical smog
1. This is formed due to buildup of sulphur oxides and particulate matter from fuel combustion.	1. This is formed due to photochemical reaction of sunlight on the nitrogen oxides and hydrocarbons produced by automobiles and factories.
2. It involves smoke and fog.	2. It does not involve any smoke or fog.
3. It occurs in cool humid climate (in winter).	3. It occurs in warm, dry and sunny climate (in summer).
4. This type of smog was first observed in London in 1952.	4. This type of smog was first observed in Los Angeles in 1950.
5. It has high concentration of SO_2 and, therefore, is reducing in character.	5. It has high concentration of oxidising agents and, therefore, is oxidising in character.
6. It causes bronchitis and irritation *i.e.*, problems in lungs.	6. It causes irritation in eyes.

Q. 11. What is the importance of measuring BOD of a water body?

Ans. BOD is the measure of level of pollution caused by organic biodegradable material in a water body. The clean water would have a BOD value of less than 5 ppm whereas higher values of BOD indicate polluted water.

Q. 12. Define eutrophication.

Ans. The process of nutrient enrichment of water bodies and subsequent loss of biodiversity is called eutrophication.

Chapter Summary

Key Terms

- **Contaminant:** A substance which does not occur in nature but is introduced by human activity into the atmosphere effecting its composition.
- **Pollution:** The addition of any foreign material or any physical change occurring in nature which may harm or affect living organisms directly or indirectly.
- **Smog:** A combination of smoke and fog laced with SO_2
- **Acid rain** Rain water containing acids such as H_2SO_4 and HNO_3 and has pH of 4–5.
- **Greenhouse effect:** Global warming due to re-emision of sun's energy absorbed by earth followed by its absorption by CO_2 molecules and water vapour near the earth and then radiation back to the earth.
- **Green chemistry:** A strategy to eliminate toxic, persistent substances from the environment.

QUICK CHAPTER ROUND UP

AIR POLLUTANTS

Primary pollutants
- harmful chemical substance that directly enters the air

Secondary pollutants
- harmful chemical substance that is formed in the air by chemical reactions

Common air pollutants
- CO, SO_2, NO, NO_2 H_2S, Cl_2, NH_3, hydrocarbons, particulates, chlorofluorocarbons

$\Rightarrow$ **CO is the major air pollutant**

SMOG
- is a mixture of smoke and fog.
- **Classical smog:** formed by the combination of smoke, dust and fog containing sulphur dioxide from polluted air.
- **Photochemical smog:** formed by the combination of smoke, dust and fog with an air pollutant in the atmosphere as a result of photochemical reaction.
- **Peroxyacylnitrate (PAN)** is a constituent of photochemical smog.

$$R-\underset{\underset{O}{\|}}{C}OONO_2$$

ACID RAIN
- When the pH of the rain water falls below 5.6, it becomes acidic and is called **acid rain.**
- It is rain water containing acids such as HNO_3 and H_2SO_4 which are formed by the oxides of nitrogen and sulphur present in air as pollutants.

- Acid rain reacts with statues made of marble, limestone, etc. Acid rain reacts with marble ($CaCO_3$).

$$CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + H_2O + CO_2$$

- As a result, the marble becomes pitted and weakened mechanically because the soluble salts are easily leached out by rain water.
- **Acid rain attacks marble of Taj Mahal of Agra.**

OZONE BLANKET
- The thick layer of ozone is called ***ozone blanket*** because it absorbs harmful ultra-violet rays given out by the sun. Therefore, the ozone layer is also known as **protective shield.**
- The ozone layer is getting depleted due to some natural processes or industrial activities
- The depletion of ozone layer is because of its reactions with chlorofluorocarbons (CFC)

GREEN HOUSE EFFECT
- The warming of the earth or global warming due to re-emission of sun's energy absorbed by the earth followed by its absorption by carbon dioxide molecules and water vapour present near the earth and then its radiation back to the earth is called greenhouse effect.

▸ Green house gases are
CO_2, CH_4, O_3, H_2O vapour, CFCs

WATER POLLUTION

- Water can be polluted by pathogens, heavy metals and pesticides

BOD & COD
- Amount of oxygen required by microorganisms to break down the organic matter present in certain volume of a sample of water is called biochemical oxygen demand, BOD
- Chemical oxygen demand (COD) is a measure of biological oxidisable as well as biological inert organic matter
- Clean water would have BOD value <5 ppm while BOD of >17 indicates highly polluted water.

Contaminants in Water
- pH of drinking water should be between 5.5. to 9.5.
- F^- ion concentration should be upto 1 – 1.5 ppm.
- F^- ions make the enamel on teeth harder by converting $[3Ca_3(PO_4)_2.Ca(OH)_2]$ to $[3Ca_3(PO_4)_2.CaF_2]$
- Excessive concentration of sulphate above 500 ppm produces laxative effects.
- Excessive nitrate causes methemoglobinemia **(blue baby syndrome)**.
- Excessive lead causes anaemia, kidney dysfunction, brain damage.

Pesticides
- **Insecticides.** DDT, malathion, carbaryl, BHC
- **Herbicides.** Sodium chlorate, sodium arsenate, 2, 4-dichlorophenoxy acid, triazines
- **Fungicides.** Thiram, phenyl mercury acetate, bordeaux mixture
- **Rodenticides.** Warfarin, zinc phosphate

- **Green chemistry** is a strategy to eliminate toxic, persistent substances from the environment.

NCERT FILE Solved

NCERT Textbook Exercises

Q. 1. Define environmental chemistry.

Ans. Environmental chemistry is defined as the branch of science which deals with study of origin, transport, reactions, effects and fates of chemical species in the environment. It deals with social, economical, biological, physical and chemical interrelations with our surroundings.

Q. 2. Explain tropospheric pollution in 100 words.

Ans. The tropospheric pollution occurs because of the presence of undesirable gaseous and solid particles in the air. The main pollutants in the troposphere are as follows:

(*i*) **Gaseous air pollutants**. The gaseous air pollutants include oxides of sulphur (SO_2, SO_3), nitrogen (NO, NO_2), carbon (CO, CO_2), hydrogen sulphide (H_2S), hydrocarbons, ozone and other oxidants.

(*ii*) **Particulate pollutants:** These pollutants are dust, fumes, mist, spray, smoke, etc.

Q. 3. Carbon monoxide gas in more dangerous than carbon dioxide gas. Why?

Ans. Carbon monoxide is a poisonous gas and it binds to haemoglobin of the blood more readily (about 200 times) than oxygen to form carboxy haemoglobin.

$$Hb + CO \rightleftharpoons HbCO$$

Carboxy haemoglobin

The presence of CO, therefore, reduces the amount of haemoglobin available in the blood for the transport of oxygen to the body cells. The harmful effects of enhaling increasing amounts of CO include reduction in awarness of judgement, dizziness, weak eye sight, headache, nervousness and cardiovascular disorders. At higher concentrations of CO, suffocation, loss of consciousness or even death after several hours. However, CO_2 does not combine with haemoglobin and hence is less harmful pollutant. CO_2 is main contributor towards, green house effect and global warming.

Q.4. List gases which are responsible for greenhouse effect.

Ans. CO_2 is the main gas which causes greenhouse effect. Other greenhouse gases are methane, ozone, water vapour, nitrous oxide, chlorofluorocarbons (CFC's).

Q. 5. Statues and monuments in India are affected by acid rain. How?

Ans. The air around statues and monuments in India contains fairly high concentrations of oxides of sulphur and nitrogen. This is mainly because of a large number of industries and power plants in the nearby areas. The presence of these oxides cause acid rain. This acid rain causes extensive damage to statues and monuments because limestone reacts with rain water and gets damaged.

$$CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + CO_2 + H_2O$$

(From acid rain)

As a result, these monuments are being slowly eaten away and the marble gets discoloured and lusterless.

Q. 6. What is smog? How is classical smog different from photochemical smog?

Ans. Smog is a major air pollutant in big cities. It is a mixture of smoke, dust particles and small drops of fog.

Smoke + Fog $\longrightarrow$ Smog

Differences between classical and photochemical smog. *Refer Conceptual Questions, Q, 10 (Page 28).*

Q. 7. Write down the reactions involved during the formation of photochemical smog.

Ans. *Refer Text page 12.*

Q. 8. What are the harmful effects of photochemical smog and how can they be controlled?

Ans. *Refer Text page 12.*

Q. 9. What are the reactions involved for ozone layer depletion in the stratosphere?

Ans. *Refer Text page 15.*

Q. 10. What do you mean by ozone hole? What are its consequences?

Ans. *Refer Text page 15–16.*

Q. 11. What are the major causes of water pollution? Explain.

Ans. *Refer Text page 19.*

Q. 12. Have you ever observed any water pollution in your area? What measures would you suggest to control it?

Ans. *Please try yourself.*

Q. 13. What do you mean by Biochemical Oxygen Demand (BOD)?

Ans. *Refer Text page 20-21.*

Q. 14. Do you observe any soil pollution in your neighbourhood? What efforts will you make for controlling the soil pollution?

Ans. *Please try yourself.*

Q. 15. What are pesticides and herbicides? Explain giving examples.

Ans. Pesticides are synthetic chemicals used for destroying pests. These are used to kill or destroy unwanted dangerous species of plants and animals. These are basically synthetic toxic chemicals with ecological repercursions. The repeated use of the same or similar pesticides make some pests resistant to that group of pesticides, thereby, making the pesticides

uneffective. For example, when insect resistance of DDT increased, other organic toxines such as Aldrin and Dieldrin, etc. were introduced. Most of the organic toxins are water insoluble and non-biodegradable. Therefore, these high persistent toxins are transferred from lower trophic level to higher trophic level through food chain. Over the time, the concentration of toxins in higher animals reach a level which causes serious metabolic and physiological disorders. Herbicides are used to kill weeds or undesirable vegetations. For example, sodium chlorate ($NaClO_3$), sodium arsenate ($NaAsO_3$), 2, 4 dichlorophenoxy acid, triazines, etc.

Q. 16. What do you mean by green chemistry? How will it help decrease environmental pollution?

Ans. *Refer Text pages 25-26.*

Q. 17. What would have happended if the green-house gases were totally missing in the earth's atmosphere? Discuss.

Ans. The solar energy radiated back from the earth surface is absorbed by greenhouse gases such as CO_2, CH_4, O_3, CFC's, water vapour, etc. present near the earths surface. Therefore, they heat up the atmosphere near the earths surface and keep it warm. Therefore, they keep the temperature of earth constant and help in growth of plants and existence of life on earth. If there are no greenhouse gases, there would have no vegetation on earth and hence no life on earth.

Q. 18. A large number of fish are suddenly found floating dead on a lake. There is no evidence of toxic dumping but you find an abundance of phytoplankton. Suggest a reason for the fish kill.

Ans. Excessive phytoplanktons (*i.e.*, organic pollutants such as leaves, grass, trash, etc.) present in water is biodegradable. A large population of bacteria decompose this organic matter in water. As a result, they consume the oxygen dissolved in water and therefore, the concentration of dissolved oxygen becomes low. If the concentration of dissolved oxygen in water becomes below 6 ppm, the survival of fish becomes difficult. Hence the fish die and float dead on lake.

Q. 19. How can domestic waste be used as manure?

Ans. Domestic wastes consist of two types of materials; biodegradable such as leaves, rotten food, etc.and non-biodegradable such as glass, plastic, metal scrap, etc. The non-biodegradable waste is sent to industry for recycling. On the other hand, the biodegradable waste should be deposited in the land fills on the nearby areas. With the passage of time, it gets converted into useful manure (compost).

Q. 20. For your agricultural field or garden you have developed a compost producing pit. Discuss the process in the light of bad odour, flies and recycling of wastes for a good produce.

Ans. The compost is very useful for agriculture as a fertilizer. But the compost producing pits may give bad odour and flies. Therefore, the compost producing pit should be set up at a suitable place or in a tin to protect ourselves from bad odour and flies. It must be kept covered so that flies connot enter into it and there is not much of bad odour.

NCERT Exemplar Problems

Note: *Objective Questions from Exemplar Problems are given in Competition File, page 41*

Subjective Questions

Short Answer Questions *Carrying 2 or 3 marks*

Q. 1. Green house effect leads to global warming. Which substances are responsible for green house effect?

Ans. The heating of earth due to trapping of radiation is called green house effect. The gas such as CO_2, CH_4, N_2O, $CFCl_3$, CF_2Cl_2, O_3 etc. trap these radiations and are called greenhouse gases.

Q. 2. Acid rain is known to contain some acids. Name these acids and where from they come in rain?

Ans. Acid rain contains acids such as HNO_3, H_2SO_4 and H_2CO_3 (alongwith small amount of HCl).
HNO_3 is formed by the oxidation of NO present in air to NO_2 and NO_3 and subsequent dissolution in water.
H_2SO_4 is formed by the oxidation of SO_2 present in air to SO_3 and subsequent dissolution in water.
H_2CO_3 is formed by the dissolution of CO_2 of the air in water.

Q. 3. Ozone is a toxic gas and is a strong oxidising agent even then its presence in the stratosphere is very important. Explain what would happen if ozone from this region completely removed ?

Ans. Ozone is an important constituent of the stratosphere. Ozone layer acts as a protective blanket or protective shield because it is very effective in absorbing harmful ultra-violet rays given by the sun. Since living cells can be destroyed by ultra-violet radiations, the ozone layer protects us from its damaging effects.

Q. 4. Dissolved oxygen in water is very important for aquatic life. What processes are responsible for the reduction of dissolved oxygen in water?

Ans. The discharge of human sewage and organic waste from paper and pulp industries and leaves, grass, trash etc. in water result in growth of phytoplanktons. These micro-organisms which decompose this organic matter require oxygen. As a result, amount of oxygen in water of lakes, etc. decreases.

Q. 5. On the basis of chemical reactions involved, explain how do chlorofluorocarbons cause thinning of ozone layer in stratosphere.

Ans. Chlorofluorocarbons are stable compounds. They move to stratosphere by random diffusion. These undergo decomposition in the presence of sunlight to release Cl atoms. These Cl atoms cause catalytic chemical reactions and cause significant depletion of ozone layer as shown below :

$$CF_2Cl_2 \xrightarrow{h\nu} Cl^{\bullet} + CF_2Cl^{\bullet}$$

$$Cl^{\bullet} + O_3 \longrightarrow ClO^{\bullet} + O_2$$

$$ClO^{\bullet} + O \longrightarrow Cl^{\bullet} + O_2$$

Q. 6. What could be the harmful effects of improper management of industrial and domestic solid waste in a city?

Ans. If the domestic waste in a city is not properly managed, it may go into sewers or may be eaten up by the cattle.

The non-biodegradable waste such as polythene bags, metal scraps, etc may block the sewers. The polythene bags if swallowed by the cattle can result in their death.

Similarly, if industrial waste is not properly managed, it will cause pollution of air, water and soil.

Q. 7. During an educational trip, a student of botony saw a beautiful lake in a village. She collected many plants from that area. She noticed that villagers were washing clothes around the lake and at some places waste material from houses was destroying its beauty.

After few years, she visited the same lake again. She was surprised to find that the lake was covered with algae, stinking smell was coming out and its water had become unusable. Can you explain the reason for this condition of the lake?

Ans. The inflow of domestic waste from houses and fertilizer of plants and the entry of soaps and detergents result into accumulation of phosphate in water. As a result, formation of algae increases which covers the water surface and concentration of dissolved oxygen decreases. Hence a process called eutrophication occurs.

Q. 8. What are biodegradable and non-biodegradable pollutants?

Ans. Biodegradable pollutants are those which can be decomposed by bacteria. For example, dust particles, sewage, cow dung etc.

Non-biodegradable pollutants are those which cannot be decomposed by bacteria. For example, plastic materials, mercury, aluminium, DDT, etc.

Q. 9. What are the sources of dissolved oxygen in water?

Ans. The main sources of dissolved oxygen in water are :

(*i*) Photosynthesis (*ii*) Natural aeration

(*iii*) Mechanical aeration

Q. 10. What is the importance of measuring BOD of a water body?

Ans. BOD is the measure of level of pollution caused by organic biodegradable material in a water body. The clean water would have a BOD value of less than 5 ppm whereas higher values of BOD indicate polluted water.

Q. 11. Why does water covered with excessive algal growth become polluted?

Ans. Presence of excessive algal growth shows that water contains a lot of phosphate due to inflow of fertilizers, etc from the surroundings. Hence, such a sample of water is polluted.

Q. 12. A factory was started near a village. Suddenly villagers started feeling the presence of irritating vapours in the village and cases of headache, chest pain, cough, dryness of throat and breathing problems increased. Villagers blamed the emissions from the chimney of the factory for such problems. Explain what could have happened. Give chemical reactions for the support of your explanation.

Ans. The symptoms observed in villagers show the presence of oxides of nitrogen and sulphur in the environment. These must be coming out of the chimney of the factory. This is due to the combustion of fossil fuels such as coal, oil, natural gas, gasoline etc. to produce high temperature at which oxidation of atmospheric nitrogen takes place forming nitric oxide (NO) and nitrogen dioxide (NO_2) as:

$$N_2 + O_2 \underset{}{\overset{1200\text{–}1750^{\circ}C}{\rightleftharpoons}} 2NO$$

$$2NO + O_2 \overset{1100^{\circ}C}{\rightleftharpoons} 2NO_2$$

The sulphur present in coal and fuel oil on combustion gives SO_2. Sulphur dioxide is also produced by the roasting of sulphide ores such as copper pyrite ($CuFeS_2$), iron pyrite (FeS_2), copper glance (Cu_2S) etc.

$$Cu_2S + O_2 \longrightarrow 2Cu + SO_2$$

$$2FeS_2 + 5O_2 \longrightarrow 2FeO + 4SO_2$$

Q. 13. Oxidation of sulphur dioxide into sulphur trioxide in the absence of a catalyst is a slow process but this oxidation occurs easily in the atmosphere. Explain how does this happen. Give chemical reactions for the conversion of SO_2 into SO_3.

Ans. The conversion of sulphur dioxide into sulphur trioxide is catalysed by the presence of particulates in the air.

$$2SO_2 + O_2 \xrightarrow{\text{Particulates}} 2SO_3$$

Q. 14. From where does ozone come in the photochemical smog?

Ans. In the presence of sunlight, ultra violet rays convert NO_2 present in air to NO and atomic oxygen. Some of the oxygen atoms combine with O_2 in the air to form ozone.

$$NO_2 \xrightarrow[\text{radiation}]{\text{U.V.}} NO + O$$

$$O_2 + O \longrightarrow O_3$$

Q. 15. How is ozone produced in stratosphere?

Ans. Ozone in stratosphere is formed by the photochemical reaction of oxygen as:

$$O_2 \xrightarrow{h\nu} O + O$$
$$O + O_2 \longrightarrow O_3$$

Q. 16. Ozone is a gas heavier than air. Why does ozone layer not settle down near the earth?

Ans. Ozone layer is formed in the stratosphere at an altitude of 25 – 30 km from the earth's surface. At this altitude, the force of gravity is negligible and therefore, ozone layer does not settle down.

Q. 17. Some time ago formation of polar stratospheric clouds was reported over Antarctica. Why were these formed? What happens when such clouds break up by warmth of sunlight?

Ans. *Refer text (page 17-18).*

Q. 18. A person was using water supplied by Municipality. Due to shortage of water he started using underground water. He felt laxative effect. What could be the cause?

Ans. The laxative effect is observed only when the concentration of sulphates in water is greater than 500 ppm. Sulphate is harmless at moderate concentration but concentration above 500 ppm produces laxative effects and hypertension.

Long Answer Questions *Carrying 5 marks*

Q. 19. How can you apply green chemistry for the following:

(*i*) to control photochemical smog.

(*ii*) to avoid use of halogenated solvents in drycleaning and that of chlorine in bleaching.

(*iii*) to reduce use of synthetic detergents,

(*iv*) to reduce the consumption of petrol and diesel.

Ans. (*i*) *Refer Text (Page 25).*

(*ii*) *Refer Text (Page 26).*

(*iii*) Soaps should be used in place of synthetic detergents because soaps are 100% biodegradable and donot cause any pollution problems. Nowadays, soft detergents are available which are biodegradable and hence these may be used.

(*iv*) CNG (Condensed Natural Gas) may be used because it causes less pollution and electrical vehicles which have zero pollution should be used.

Q. 20. Green plants use carbon dioxide for photosynthesis and return oxygen to the atmosphere, even then carbon dioxide is considered to be responsible for green house effect. Explain why?

Ans. The amount of CO_2 produced due to human activities such as burning of fossil fuels (coal, natural gas, petroleum, etc.) and production of lime from limestone is much more than that consumed during photosynthesis. Moreover, consumption in photosynthesis has further decreased due to deforestation.

Q. 21. Explain how does green house effect cause global warming.

Ans. *Refer Text (Page 16).*

Q. 22. A farmer was using pesticides on his farm. He used the produce of his farm as food for rearing fishes. He was told that fishes were not fit for human consumption because large amount of pesticides had accumulated in the tissues of fishes. Explain how did this happen?

Ans. The pesticides travelled from the soil into the crops produced by the farmer. From the crops, used as food for fish, the pesticides entered into water from where they finally entered into the bodies of the fishes. Therefore, the fishes were not fit for human consumption.

Q. 23. For dry cleaning, in the place of tetrachloroethene, liquefied carbon dioxide with suitable detergent is an alternative solvent. What type of harm to the environment will be prevented by stopping use of tetrachloroethene? Will use of liquefied carbon dioxide with detergent be completely safe from the point of view of pollution? Explain.

Ans. Tetrachloroethene ($Cl_2C = CCl_2$) has earlier been used as a solvent for dry cleaning. This compound is suspected to be carcinogenic and contaminates the ground water. This harmful effect has not been prevented by using liquefied CO_2 alongwith suitable detergent.

However, use of liquefied CO_2 with detergent will not be completely safe because detergents also cause pollution, as most of the detergents are non-biodegradable. Moreover, liquefied CO_2 will ultimately enter into the atmosphere and add to greenhouse effect.

QUICK MEMORY TEST

A. Say True or False

1. Acid rain is due to the presence of oxides of sulphur in air.
2. Classical smog is reducing in nature.
3. Ozone is present in stratosphere of the atmosphere.
4. N_2 and O_2 are the two main greenhouse gases.
5. Excess sulphate in water causes blue baby syndrome.
6. The clean water would have a BOD value of more than 17.
7. Fish grows better in warm water than in cold water.
8. The major cause of ozone layer destruction is the release of freons in the atmosphere.
9. Mercury is a biodegradable pollutant.
10. Mesosphere is higher than stratosphere.

B. Complete the missing links

1. Carbon monoxide combines with haemoglobin of red blood corpuscles to form ..... .
2. The abbreviation PAN stands for ..... .
3. London smog is ..... in nature.
4. The gas leaked in *Bhopal gas tragedy* was ..... .
5. Acid rain contains ..... and ..... and has pH of ..... .
6. The loss of green colour in plants due to the presence of even a low concentration of SO_2 is called ..... .
7. The amount of dissolved oxygen needed by aerobic bacteria to break down the organic matter is called ..... .
8. The process of nutrient enrichment of water bodies and subsequent loss of biodiversity is called ..... .
9. The heating of earth due to trapped radiation is called ..... .
10. Anything which is affected by the pollutants is called ..... .

C. Choose the correct alternative

1. Carboxyhaemoglobin is *more / less* stable than oxyhaemoglobin.
2. Mercury is a *biodegradable / non-biodegradable* pollutant.
3. When pH of rain becomes *more / less* than 5.6, it becomes acid rain.
4. Photochemical smog is *oxidising / reducing* in nature.
5. Major pollutant in air is *CO / SO_2*.
6. Natural decay of animal and vegetable matter is the main source of *H_2S / NO* air pollutant.
7. The main greenhouse gas is *SO_2 / CO_2*.
8. Chlorofluorocarbons *cause damage / prevent damage* of ozone layer.
9. Water having BOD value of 5 ppm is *highly polluted / clean* water.
10. The region of stratosphere is *above / below* troposphere.

Answers QUICK MEMORY TEST

A. Say True or False

1. **False :** Acid rain is due to the oxides of sulphur and nitrogen in the air.
2. True
3. True
4. False
5. **False:** Excessive nitrate causes blue baby syndrome.
6. False
7. False
8. True
9. **False :** Mercury is a non-biodegradable pollutant
10. True.

B. Complete the missing links

1. carboxyhaemoglobin
2. peroxyacyl nitrates
3. reducing
4. methyl isocyanate
5. sulphuric acid, nitric acid, 4 to 5.
6. chlorosis
7. biological oxygen demand (BOD)
8. eutrophication
9. greenhouse effect
10. receptor.

C. Choose the correct alternative

1. more
2. non-biodegradable
3. less
4. oxidising
5. CO
6. H_2S
7. CO_2
8. cause damage
9. clean
10. above.

Revision Exercises

Very Short Answer Questions *carrying 1 mark*

1. Define pollutant.
2. Why is carbon monoxide a pollutant although it is a colourless and odourless gas ?
3. Name two gaseous air pollutants.
4. Which region of atmosphere contains ozone ?
5. Define environmental chemistry.
6. Name two greenhouse gases.
7. Name four regions of atmosphere.
8. Name major air pollutant.
9. Why is ozone called protective shield ?
10. What is an ionosphere ? What does it contain ?
11. What is greenhouse effect ?
12. Name two oxides of nitrogen which are pollutants in the atmosphere.
13. What is photochemical smog ?
14. What is PAN ?
15. Why is CO a potentially dangerous air pollutant ?
16. Name two highly toxic compounds of mercury.
17. Why is CO a very harmful pollutant of air ?
18. List two health problems caused by SO_2.

19. Name the compounds which cause the depletion of ozone layer.

20. How is ozone formed in the atmosphere ?

21. How does CO_2 cause environmental pollution ?

Short Answer Questions *Carrying 2 or 3 marks*

1. What is environmental chemistry ? Discuss its social relevance.

2. What is the difference between pollutant and contaminant?

3. Discuss the sources, sinks of CO as air pollutant. How is this pollution controlled ?

4. What is the difference between the primary and secondary pollutants ? Give examples.

5. How can internal combustion engines be modified to make auto exhaust free from pollutants ?

6. What is the major air pollutant ? Give its important sources and its harmful effects on human life.

7. Carbon monoxide is more dangerous than carbon dioxide gas. Explain.

8. Explain giving reasons "the presence of CO reduces the amount of haemoglobin av ailable in the blood for carying oxygen to the body cells".

9. Discuss the effect of particulate pollution on human life.

10. What is photochemical smog ? discuss the possible mechanism of its formation.

11. What is acid rain ? What are its harmful effects ?

12. How does oxygen reach water ? How is the oxygen content of a sample of water measured ?

13. What do you understand by the term eutrophication? How does it threaten the development of fish ?

14. What is pneumoconiosis ? How does it occur ?

15. What are smogs ? Distinguish between classical and photochemical smogs.

16. How does SO_2 cause pollution ? Explain as to how this can be checked.

17. Define the terms : Pollutant, contaminate, source and sink. Give one example of each.

18. What is acid rain ? Describe its role in environmental pollution.

19. Write brief account of air pollution caused by oxides of nitrogen.

20. "Carbon dioxide is non-toxic but it is an important environmental problem facing us at present." Comment on the statement.

21. Giving equations explain how does nitrous oxide present in atmosphere cause depletion of ozone.

22. Why is the use of chlorofluoro carbons being discouraged ? Explain.

23. What do you understand by Greenhouse effect ? What are the major Greenhouse gases ?

24. Explain the difference between primary and secondary pollutants.

25. What is green chemistry ? Explain.

26. Give harmful effects of depletion of ozone layer.

27. The depletion of ozone layer occurs over Antarctica during spring time and it gets replenished after spring time. Explain.

28. Why is acid rain considered a threat to Taj Mahal ?

29. Why does the rain water normally have a *p*H of about 5.6 ? When does it become acid rain?

30. Give a brief account of chemical reactions occurring in atmosphere.

31. Write down the reactions involved during the formation of photochemical smog.

32. What are harmful effects of photochemical smog and how can they be controlled ?

33. What are the reactions involved for ozone depletion in stratosphere ?

34. What are pesticides and herbicides ? Explain giving examples.

35. What do you mean by green chemistry ? How will it help to decrease environmental pollution ?

36. What are major causes of water pollution ? Explain.

37. How do chemical industries cause environmental pollution ?

38. What pollutants are released by motor vehicles ? How can we minimize damage caused by them ?

39. What do you understand by BOD and COD ? How are these determined ?

40. What do you understand by

(*i*) Polar stratospheric clouds (*ii*) Polar vortex

41. Define an environmental pollutant. What do you understand by an environmental pollution model ?

42. What is the cause of acid rain ? How is it harmful to environment ?

43. Why does greenhouse effect lead to global warming ? What could be the consequences of global warming ?

44. Write a short note on Bhopal Gas tragedy ?

45. Fish do not always grows as well as in warm as in cold water, why ?

46. "Oxygen plays a key role in the troposphere while ozone in the stratosphere" Explain.

47. What do you understand by ozone hole ? What are its consequences ? Why does it occur mainly over Antarctica ?

Long Answer Questions *Carrying 5 marks*

1. Discuss the various regions of the atmosphere. Explain the different chemical reactions occurring in the atmosphere.

2. What is air pollution ? Explain briefly the major atmospheric pollutants.

3. How is ozone formed in the atmosphere ? What are the causes of depletion of ozone layer ? Explain harmful effects of depletion of ozone layer.

4. What is greenhouse effect ? What are its effects ?

5. Write short notes on :

(*a*) Acid rain

(*b*) Green chemistry as an alternative tool for reducing pollution.

6. Discuss the sources , sinks of carbon monoxide as an air pollutant. How is this pollution controlled ?
7. Discuss briefly the pollution caused by oxides of sulphur and nitrogen.
8. Write short notes on :
   (*i*) Smog
   (*ii*) Depletion of ozone layer
   (*iii*) Greenhouse effect.
9. Discuss five major water pollutants giving their sources.
10. Explain the following :
    (*i*) Smoke (*ii*) Fumes (*iii*) Dust (*iv*) Mist
11. Explain how does green house effect cause global warming.
12. How can you apply green chemistry for the following :
    (*a*) to reduce the consumption of petrol and diesel.
    (*b*) to control photochemical smog.
    (*c*) to reduce use of synthetic detergents.
    (*d*) to avoid use of halogenated solvents in drycleaning and that of chlorine in bleaching.

Competition File

Additional Useful Information and Objective Questions

ADDITIONAL USEFUL INFORMATION

CHEMICAL AND PHOTOCHEMICAL REACTIONS IN ATMOSPHERE

Many chemical reactions are occurring in atmosphere in which oxygen plays an important role. Some of these reactions occur by the absorption of solar radiation and these reactions are called **photochemical reactions.** These chemical and photochemical reactions play a significant role in governing the chemical species present in the atmosphere. It may be noted that there are large variations in the atmosphere with regards to composition, temperature, humidity and intensity of sunlight. Therefore, different types of reactions are observed under varying atmospheric conditions.

Oxygen in the troposphere plays an important role in the processes occurring on the earth's surface. For example, oxygen is taking part in burning of fossil fuels.

$$\underset{\text{(Natural gas)}}{CH_4} + 2O_2 \longrightarrow CO_2 + 2H_2O$$

Atmospheric oxygen is also used by aerobic organisms in the degradation of organic material or in oxidation of weathering processes.

$$\text{Organic matter} + O_2 \xrightarrow{\text{Organisms}} CO_2 + H_2O$$

$$4Fe + 3O_2 \longrightarrow 2Fe_2O_3$$

The carbon dioxide and water present in the atmosphere are used by green plants in the presence of sunlight in the process of **photosynthesis** as :

$$6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{h\nu} C_6H_{12}O_6 + 6O_2$$

During photosynthesis, oxygen is again returned to the atmosphere.

In the upper atmosphere, oxygen exists in some forms which are different from those stable at lower levels. Thus, in addition to O_2 (molecular oxygen), the upper atmosphere also have O (atomic oxygen), O_2^* (excited molecular oxygen), O^* (excited atomic oxygen), O^+ (ionic oxygen) and O_3 (ozone).

The atomic oxygen is produced by photochemical dissociation of oxygen by ultraviolet radiation ($E = h\nu$).

$$O_2 + h\nu \longrightarrow O + O$$

Due to the above photochemical dissociation of O_2, molecular O_2 is virtually non-existent at very high altitudes. At altitudes exceeding 40 km only less than 10% of oxygen is present as molecular oxygen. The atomic oxygen combines in the presence of radiation to form excited oxygen atom according to the reaction

$$O + O + O \xrightarrow{h\nu} O_2 + O^*$$

The excited oxygen atom gives out visible light at 636 nm, 630 nm and 558 nm wavelength and is responsible for **air glow.** Oxygen ions (O^+) are formed when ultraviolet radiations react with oxygen atom

$$O + h\nu \longrightarrow O^+ + e^-$$

The oxygen ion is present in some regions of the ionosphere. It may be noted that the region beyond stratosphere is dominated by +ve ions such as O^+, O_2^+, NO^+ and free electrons. It is called **ionosphere.** O^+ ion also undergoes a number of other reactions such as

$$O^+ + O_2 \longrightarrow O_2^+ + O$$

$$\underset{\text{(From atmosphere)}}{O^+ + N_2} \longrightarrow NO^+ + N$$

O_2^+ may also be formed according to the reaction

$$N_2^+ + O_2 \longrightarrow N_2 + O_2^+$$

Ozone is present in the stratosphere which acts as a protective radiation shield for living organisms on earth. It is formed by photochemical reactions of oxygen as :

$$O_2 + h\nu \longrightarrow O + O$$

$$O + O_2 + M \longrightarrow O_3 + M$$

Where M is another species like a molecule of N_2 or O_2. It absorbs the excess energy liberated by the above reactions and hence stabilize the O_3 molecule. Ozone strongly absorbs ultraviolet light in the region of 220– 330 nm according to the following reactions :

$$O_3 + h\nu \longrightarrow O_2 + O$$

$$O_3 + O \longrightarrow O_2 + O_2$$

Competition File

Atomic oxygen may also be eliminated by the reaction

$$O + O + M \longrightarrow O_2 + M$$

Ozone in the stratosphere is destroyed by reaction with reactive hydroxyl radicals or nitric oxide, etc.

$$O_3 + HO^{\bullet} \longrightarrow O_2 + HOO^{\bullet}$$

(Hydroxyl radical)

$$HOO^{\bullet} + O \longrightarrow HO^{\bullet} + O_2$$

Similarly,

$$O_3 + NO \longrightarrow NO_2 + O_2$$

Nitric oxide

$$NO_2 + O \longrightarrow NO + O_2$$

Nitric oxide is produced in the stratosphere below 30 km by the reaction of nitrous oxide (N_2O) with excited oxygen atoms. Nitrous oxide originates from the microbiological processes occurring in the atmosphere.

$$NO_2 + O^* \longrightarrow 2NO$$

Above 30 km in the stratosphere it is produced by ionizing radiation on nitrogen

$$N_2 + h\nu \longrightarrow N + N$$

$$O_2 + N \longrightarrow NO + O$$

OBJECTIVE TYPE QUESTIONS

A Topicwise MULTIPLE CHOICE QUESTIONS *with only one correct answer*

Air Pollution

A1. The major air pollutant is :
(*a*) CO (*b*) Oxides of nitrogen
(*c*) Soot (*d*) Oxides of sulphur.

A2. The region closest to earth's surface is :
(*a*) stratosphere (*b*) mesosphere
(*c*) troposphere (*d*) thermosphere.

A3. The major source of CO pollution is :
(*a*) industrial processes (*b*) vehicular exhaust
(*c*) forest fires (*d*) volcanic activity.

A4. Increased concentration of CO_2 in atmosphere is responsible for :
(*a*) greenhouse effect (*b*) acid rain
(*c*) lack of photosynthesis (*d*) death of aquatic life.

A5. Which of the following oxides of nitrogen is not common air pollutant ?
(*a*) NO_2 (*b*) N_2O (*c*) NO (*d*) N_2O_5.

A6. White lung cancer is caused by
(*a*) asbestos (*b*) silica
(*c*) textiles (*d*) paper

A7. Which one of the following particulates is most toxic?
(*a*) fly ash (*b*) soot
(*c*) inorganic compound (*d*) smog.

A8. Besides CO_2, other greenhouse gas is
(*a*) CH_4 (*b*) N_2 (*c*) Ar (*d*) O_2.

A9. PAN stands for
(*a*) $CH_2 = O$ (*b*) $CH_2 = CH\ CH = O$
(*c*) $CH_3\,\underset{\underset{O}{\|}}{C}OONO_2$ (*d*) $CH_3CH_2O - N = O$.

A10. Depletion of ozone layer causes
(*a*) blood cancer (*b*) breast cancer
(*c*) lung cancer (*d*) skin cancer

A11. Acid rains are produced by :
(*a*) excess release of carbon monoxide by incomplete combustion.
(*b*) excess formation of carbon dioxide by combustion and respiration.
(*c*) excess production of NH_3 by industries.
(*d*) excess NO_2 and SO_2 from burning fossil fuels.

A12. Oxides of sulphur and nitrogen are important pollutants of :
(*a*) Water (*b*) Air
(*c*) Soil (*d*) All of these.

A13. In upper stratosphere, ozone protects us from :
(*a*) infra-red radiations (*b*) ultra-violet radiations
(*c*) carbon dioxide (*d*) peroxyacetyl nitrate.

A14. Burning of fossil fuels is the main source of :
(*a*) Nitrogen dioxide (*b*) Nitric oxide
(*c*) Nitrous oxide (*d*) Sulphur dioxide.

A15. Which of the following gases is not a green house gas?
(*a*) CO (*b*) O_3
(*c*) CH_4 (*d*) H_2O vapour

A16. Taj Mahal is threatened by pollution from :
(*a*) Oxygen (*b*) Carbon dioxide
(*c*) Sulphur dioxide (*d*) Chlorine.

A17. Which of the following is the primary precursor of photochemical smog ?
(*a*) Ozone (*b*) Peroxyacetyl nitrate
(*c*) NO_2 (*d*) CO_2.

A18. The main contributor of acid rain is :
(*a*) H_2SO_4 (*b*) $CaCO_3$ (*c*) CH_3COOH (*d*) PAN.

A19. The main culprit for the depletion of protective ozone layer is :
(*a*) Oxygen (*b*) CFCs
(*c*) Oxides of S (*d*) Particulate matter.

A20. It is not advised to sleep in a closed room with a coke fire burning inside on a cold day because of harmful effects of :
(*a*) CO
(*b*) Carbon particulates
(*c*) CO_2
(*d*) SO_2 present as impurity in coke fire.

Answers

A1. (*a*) **A2.** (*c*) **A3.** (*b*) **A4.** (*a*) **A5.** (*d*) **A6.** (*c*) **A7.** (*b*) **A8.** (*a*) **A9.** (*c*) **A10.** (*d*)
A11. (*d*) **A12.** (*b*) **A13.** (*b*) **A14.** (d) **A15.** (*a*) **A16.** (*c*) **A17.** (*c*) **A18.** (*a*) **A19.** (*b*) **A20.** (*a*)

Competition File

A21. Bhopal Gas Tragedy was caused by :
(a) Methyl amine (b) Methyl isocyanate
(c) Phosgene (d) Chloroform.

A22. Which of the following is responsible for depletion of the ozone layer in the upper strata of the atmosphere ?
(a) Fullerenes (b) Freons
(c) Polyhalogens (d) Ferrocene.

A23. Most dangerous metal pollutant of automobile exhausts is
(a) Lead (b) Copper
(c) Mercury (d) Cadmium

A24. Which is most abundant hydrocarbon pollutant ?
(a) Methane (b) Propane
(c) Acetylene (d) Ethane.

Water Pollution

A25. Which of the following species containing mercury is most toxic ?
(a) CH_3Hg^+ (b) $HgCl_2$
(c) Hg_2Cl_2 (d) Hg metal.

A26. Which of the following metal has maximum recommended level in drinking water ?
(a) Cadmium (b) Zinc
(c) Aluminium (d) Iron.

A27. The clean water should have BOD value
(a) less than 5 ppm (b) 10 ppm
(c) 20 ppm (d) 100 ppm

A28. Which of the following has least permissible limit in drinking water ?
(a) Chlorides (b) Dissolved oxygen
(c) Zinc (d) Lead.

A29. COD stands for :
(a) Chemical Oxygen Demand.
(b) Controlled Oxygen Demand.
(c) Clouds causing Ozone Depletion.
(d) Chlorinated Oxygen Demand.

Soil Pollution

A30. Marble acts as a sink for
(a) metallic pollutants (b) NH_3 pollutants
(c) acidic pollutants (d) none of these.

A31. Herbicides are used to kill weeds. The common herbicide is
(a) D.D.T. (b) Triazine
(c) Methyl mercury (d) PCBS.

A32. Soil salinity can be measured by :
(a) Potentiometer (b) Calorimeter
(c) Conductivity meter (d) All of these.

A33. D.D.T. is :
(a) an antibiotic
(b) biodegradable pollutant
(c) non-degradable pollutant
(d) not a pollutant.

Answers

A21. (b) **A22.** (b) **A23.** (a) **A24.** (a) **A25.** (a) **A26.** (b) **A27.** (a) **A28.** (d) **A29.** (a) **A30.** (c) **A31.** (b) **A32.** (c) **A33.** (c)

B MULTIPLE CHOICE QUESTIONS *from competitive examinations*

AIPMT & Other State Boards' Medical Entrance

B1. Ozone in the stratosphere is depleted by
(a) CF_2Cl_2 (b) C_7F_{16}
(c) $C_6H_6Cl_6$ (d) C_6F_6 *(A.I.I.M.S. 2004)*

B2. Which one of the following is responsible for depletion of the ozone layer in the upper strata of the atmosphere?
(a) polyhalogens (b) ferrocene
(c) fullerenes (d) freons *(CBSE P.M.T. 2004)*

B3. The environmental friendly method of killing harmful insects is through the use of
(a) Insecticides (b) Sex attractants
(c) Sex hormones (d) Pesticides
(e) Antibiotics *(Kerala PMT 2008)*

B4. The process of 'eutrophication' is due to
(a) Increase in concentration of insecticide in water
(b) Increase in concentration of fluoride ion in water
(c) The reduction in concentration of the dissolved oxygen in water due to phosphate pollution in water
(d) Attack of younger leaves of a plant by peroxyacetyl nitrate
(e) Increase in concentration of radioactive substances in water. *(Kerala PMT 2008)*

B5. Green chemistry means such reactions which :
(a) Produce colour during reactions
(b) Reduce the use and production of hazardous chemicals
(c) Are related to the depletion of ozone layer
(d) Study the reactions in plants. *(CBSE Med.2008)*

B6. Which one of the following statement is not true?
(a) pH of drinking water should be between 5.5-9.5
(b) Concentration of DO below 6 ppm is good for the growth of fish.
(c) Clean water would have a BOD value of less than 5 ppm.
(d) Oxides of sulphur, nitrogen and carbon, are the most widespread air pollutant. *(AIPMT 2011)*

B7. Excess nitrate in drinking water can cause
(a) methemoglobinemia
(b) liver damage (c) kidney damage
(d) laxative effect (e) leucoderma
(Kerala PMT 2011)

Answers

B1. (a) **B2.** (d) **B3.** (b) **B4.** (c) **B5.** (b) **B6.** (b) **B7.** (a)

Competition File

B8. Which of the following is not a greenhouse gas?
(a) Methane (b) Ozone
(c) Carbon dioxide (d) Nitrogen

B9. The pH of normal rain water is
(a) 6.5 (b) 7.5
(c) 5.6 (d) 3.5
(e) 4.6 *(Kerala PMT 2012)*

B10. Which one of the following statements regarding photochemical smog is not correct ?
(a) Carbon monoxide does not play any role in photochemical smog formation.
(b) Photochemical smog is an oxidising agent in character.
(c) Photochemical smog is formed through photochemical reaction involving solar energy.
(d) Photochemical smog does not cause irritation in eyes and throat. *(A.I.P.M.T. 2012)*

B11. Which one of the following is not a common component of photochemical smog?
(a) Ozone (b) Acrolein
(c) Peroxyacetyl nitrate (d) Chlorofluorocarbons
(AIPMT 2014)

B12. Which of the following is a sink for CO?
(a) Microorganisms present in the soil
(b) Oceans
(c) Plants
(d) Haemoglobin *(NEET 2017)*

B13. Which oxide of nitrogen is not a common pollutant introduced into the atmosphere both due to natural and human activity?
(a) N_2O_5 (b) NO_2
(c) N_2O (d) NO *(NEET 2018)*

JEE (Main) & Other State Boards' Engineering Entrance

B14. The smog is essentially caused by the presence of
(a) Oxides of sulphur and nitrogen
(b) O_2 and N_2
(c) O_2 and O_3
(d) O_3 and N_2 *(A.I.E.E.E.2004)*

B15. Identify the wrong statement in the following :
(a) Acid rain is mostly because of oxides of nitrogen and sulphur
(b) Chlorofluorocarbons are responsible for ozone layer depletion
(c) Greenhouse effect is responsible for global warming
(d) Ozone layer does not permit infrared radiation from the sun to reach the earth. *(AIEEE 2008)*

B16. The ozone layer forms naturally by
(a) the interaction of CFC with oxygen
(b) the interaction of UV radiation with oxygen
(c) the interaction of IR radiation with oxygen
(d) the interaction of oxygen and water vapour
(WB JEE 2011)

B17. The maximum prescribed concentration of cadmium in drinking water in ppm is
(a) 0.05 (b) 3
(c) 2 (d) 5
(e) 0.005 *(Kerala PET 2012)*

B18. The gas emitted by supersonic jet planes that slowly depletes the concentration of ozone layer is
(a) CO (b) NO
(c) SO_2 (d) O_2
(e) HF *(Kerala PET 2012)*

B19. CCl_4 and freons
(a) are green compounds because they are green coloured
(b) deplete ozone concentration
(c) cause increase in ozone concentration
(d) have no effect on ozone concentration
(J.K.C.E.T. 2012)

B20. What is D.D.T. among the following ?
(a) A fertilizer
(b) Biodegradable pollutant
(c) Non-biodegradable pollutant
(d) Greenhouse gas *(A.I.E.E.E. 2012)*

B21. The gas leaked from a storage tank of the Union Carbide plant in Bhopal gas tragedy was
(a) Phosgene (b) Methylisocyanate
(c) Methylamine (d) Ammonia *(JEE Main 2013)*

B22. Metal ion responsible for the Minamata disease is
(a) Co^{2+} (b) Hg^{2+}
(c) Cu^{2+} (d) Zn^{2+} *(WB JEE 2014)*

B23. Among the following the one which is not a "greenhouse gas", is
(a) N_2O (b) CO_2
(c) CH_4 (d) O_2 *(WB JEE 2014)*

B24. Green chemistry deals with
(a) study of plant physiology
(b) study of extraction of natural products from plants
(c) detailed study of reactions involved in the synthesis of chlorophyll
(d) utilization of existing knowledge base for reducing the chemical hazards along with developmental activities
(e) synthesis of chemical compounds using green light.
(Kerala PET 2014)

B25. The wrong statement among the following is :
(a) Acid rain is mostly because of oxides of nitrogen and sulphur.
(b) Greenhouse effect is responsible for global warming.
(c) Ozone layer does not permit infrared radiation from the sun to reach earth.
(d) Chlorofluorocarbons are responsible for ozone layer depletion. *(J.K. CET 2015)*

Answers

B8. (d) **B9.** (c) **B10.** (d) **B11.** (d) **B12.** (a) **B13.** (a) **B14.** (a) **B15.** (d) **B16.** (b) **B17.** (e) **B18.** (b)
B19. (b) **B20.** (c) **B21.** (b) **B22.** (b) **B23.** (d) **B24.** (d) **B25.** (c)

Competition File

B26. The concentration of fluoride, lead, nitrate and iron in a water sample from an underground lake was found to be 100 ppb, 40 ppb, 100 ppm and 0.2 ppm, respectively. This water is unsuitable for drinking due to high concentration of :
(*a*) Fluoride (*b*) Lead
(*c*) Nitrate (*d*) Iron (*JEE Main 2016*)

B27. Which one of the following is not a common component of photochemical smog?
(*a*) Ozone (*b*) Acrolein
(*c*) Peroxyacetylnitrate (*d*) Chlorofluorocarbons
(*Karnataka CET 2017*)

B28. A water sample has ppm level co ncentration of following anions
$F^- = 10$; $SO_4^{2-} = 100$; $NO_3^- = 50$
the anion/anions that make/makes the water sample unsuitable for drinking is/are:
(*a*) only NO_3^- (*b*) both SO_4^{2-} and NO_3^-
(*c*) only F^- (*d*) only SO_4^{2-} (*JEE Main 2017*)

B29. Green fuel is the fuel obtained from
(*a*) bio-waste (*b*) metal waste
(*c*) plastic waste (*d*) chemical waste
(*e*) electronic waste. (*Kerala PET 2018*)

B30. Which of the following is present in maximum amount in acid rain?
(*a*) HNO_3 (*b*) H_2SO_4
(*c*) HCl (*d*) H_2CO_3 (*WB JEE 2018*)

B31. The recommended concentration of fluoride ion in drinking water is up to 1 ppm as fluoride ion is required to make teeth enamel harder by converting $[3Ca_3(PO_4)_2.\ Ca(OH)_2]$ to :
(*a*) $[CaF_2]$ (*b*) $[3(CaF_2).Ca(OH)_2]$
(*c*) $[3Ca_3(PO_4)_2.CaF_2]$ (*d*) $[3\{Ca(OH)_2\}.CaF_2]$
(*JEE Main 2018*)

B32. The molecule that has minimum/no role in the formation of photochemical smog, is
(*a*) NO (*b*) $CH_2{=}O$
(*c*) O_3 (*d*) N_2 (*JEE Main 2019*)

B33. Water samples with BOD values of 4 ppm and 18 ppm respectively, are
(*a*) Clean and highly polluted
(*b*) Clean and clean
(*c*) Highly polluted and clean
(*d*) Highly polluted and highly polluted
(*JEE Main 2019*)

Answers

B26. (*c*) **B27.** (*d*) **B28.** (*c*) **B29.** (*a*) **B30.** (*b*) **B31.** (*c*) **B32.** (*d*) **B33.** (*a*)

C MULTIPLE CHOICE QUESTIONS
with more than one correct answer

C1. The gases causing greehouse effect is/are
(*a*) CH_4 (*b*) NO_2 (*c*) SO_2 (*d*) O_3

C2. Which of the following conditions show the polluted environment?
(*a*) pH of rain water in 5.6.
(*b*) eutrophication.
(*c*) biochemical oxygen demand 10 ppm.
(*d*) amount of carbon dioxide in the atmosphere is 0.03%

C3. The acids present in acid rain are
(*a*) H_2CO_3 (b) Peroxyacetylnitrate
(*c*) H_2SO_4 (*d*) HNO_3

C4. The atmosphere surrounding us may be divided into the following regions.
(*a*) mesosphere (*b*) hemisphere
(*c*) thermosphere (*d*) catosphere

C5. The ozone layer is depleted by
(*a*) SO_2 (*b*) C_xH_y (*c*) NO (*d*) CFCs

Answers

C1. (*a, d*) **C2.** (*b,c*) **C3.** (*a,c,d*) **C4.** (*a,c*) **C5.** (*c,d*)

Assertion Reason Type Questions

The questions given below consists of an Assertion and the Reason. Use the following key to choose the appropriate answer.

(*a*) If both assertion and reason are CORRECT and reason is the CORRECT explanation of the assertion.
(*b*) If both assertion and reason are CORRECT, but reason is NOT THE CORRECT explanation of the assertion.
(*c*) If assertion is CORRECT, but reason is INCORRECT.
(*d*) If assertion is INCORRECT, but reason is CORRECT.
(*e*) If both asseriton and reason are INCORRECT.

1. Assertion : Photochemical smog is produced by oxides of nitrogen.
Reason : Vehicular pollution is a major source of oxides of nitrogen.

2. Assertion : For greenhouse effect, presence of green plants is essential.
Reason : Chlorophyll of the green plants causes green house effect.

3. Assertion : Normal rain water has a pH of about 5.6.
Reason : The pH is due to dissolution of CO_2 to form carbonic acid.

4. Assertion : In India, an oil spill occurred in Bombay in 1993.
Reason : Spreading of oil into sea is called oil spill.

Answers

1. (*b*) **2.** (*e*) **3.** (*a*) **4.** (*b*)

Competition File

5. Assertion : Higher concentration of CO_2 in atmosphere is causing global warming.
Reason : This is due to greenhouse effect.

6. Assertion : The presence of CO reduces the amount of haemoglobin available in the blood for carrying oxygen to the body cells.
Reason : CO combines with haemoglobin about 200 times less easily than oxygen to form complex.

7. Assertion : Photochemical smog is oxidising in nature.
Reason : Photochemical smog contains NO_2 and O_3, which are formed during the sequences of reactions.

8. Assertion : Ozone is destroyed by solar radiation in upper stratosphere.
Reason : Depletion of the ozone layer allows excessive UV radiations to reach the surface of earth.
(NCERT Exemplar Problem)

9. Assertion : Excessive use of chlorinated synthetic pesticides causes soil and water pollution.
Reason : These pesticides are non-biodegradable.
(NCERT Exemplar Problem)

10. Assertion : The pH of acid rain is less than 5.6.
Reason : Carbon dioxide present in the atmosphere dissolves in rain water and forms carbonic acid. *(NCERT Exemplar Problem)*

11. Assertion : If BOD level of water in a reservoir is less than 5 ppm it is highly polluted.
Reason : High BOD means low activity of bacteria in water. *(NCERT Exemplar Problem)*

12. Assertion : Green house effect was observed in houses made of green glass which are used to grow plants.
Reason : Green house name has been given because glass houses are made of green glass. *(NCERT Exemplar Problem)*

Answers

5.(*a*) **6.** (*c*) **7.** (*a*) **8.** (*d*) **9.**(*a*) **10.** (*b*) **11.** (*e*) **12.** (*e*)

NCERT Exemplar Problems

Objective Questions

Multiple Choice Questions (Type-I)

1. Which of the following gases is not a green house gas?
(*a*) CO (*b*) O_3
(*c*) CH_4 (*d*) H_2O vapour

2. Photochemical smog occurs in warm, dry and sunny climate. One of the following is not amongst the components of photochemical smog, identify it.
(*a*) NO_2 (*b*) O_3
(*c*) SO_2 (*d*) Unsaturated hydrocarbon

3. Which of the following statement is **not** true about classical smog?
(*a*) Its main components are produced by the action of sunlight on emissions of automobiles and factories.
(*b*) Produced in cold and humid climate.
(*c*) It contains compounds of reducing nature.
(*d*) It contains smoke, fog and sulphur dioxide.

4. Biochemical Oxygen Demand, (BOD) is a measure of organic material present in water. BOD value less than 5 ppm indicates a water sample to be ____ .
(*a*) rich in dissolved oxygen
(*b*) poor in dissolved oxygen.
(*c*) highly polluted.
(*d*) not suitable for aquatic life

5. Which of the following statements is wrong?
(*a*) Ozone is not responsible for green house effect.
(*b*) Ozone can oxidise sulphur dioxide present in the atmosphere to sulphur trioxide.
(*c*) Ozone hole is thinning of ozone layer present in stratosphere.
(*d*) Ozone is produced in upper stratosphere by the action of UV rays on oxygen.

6. Sewage containing organic waste should be disposed in water bodies because it causes major water pollution. Fishes in such a polluted water die because of
(*a*) Large number of mosquitoes.
(*b*) Increase in the amount of dissolved oxygen.
(*c*) Decrease in the amount of dissolved oxygen in water.
(*d*) Clogging of gills by mud.

7. Which of the following statements about photochemical smog is wrong?
(*a*) It has high concentration of oxidising agents.
(*b*) It has low concentration of oxidising agents.
(*c*) It can be controlled by controlling the release of NO_2, hydrocarbons, ozone etc.
(*d*) Plantation of some plants like pinus helps in controlling photochemical smog.

8. The gaseous envelope around the earth is known as atmosphere. The lowest layer of this is extended upto 10 km from sea level, this layer is _____ .
(*a*) Stratosphere (*b*) Troposphere
(*c*) Mesosphere (*d*) Hydrosphere

Answers

1. (*a*) **2.** (*c*) **3.** (*a*) **4.** (*a*) **5.** (*a*) **6.** (*c*) **7.** (*b*) **8.** (*b*)

Competition File

9. Dinitrogen and dioxygen are main constituents of air but these do not react with each other to form oxides of nitrogen because _____ .
(*a*) the reaction is endothermic and requires very high temperature.
(*b*) the reaction can be initiated only in presence of a catalyst.
(*c*) oxides of nitrogen are unstable.
(*d*) N_2 and O_2 are unreactive.

10. The pollutants which come directly in the air from sources are called primary pollutants. Primary pollutants are sometimes converted into secondary pollutants. Which of the following belongs to secondary air pollutants?
(*a*) CO (*b*) Hydrocarbon
(*c*) NO (*d*) Peroxyacetyl nitrate

11. Which of the following statements is correct?
(*a*) Ozone hole is a hole formed in stratosphere from which ozone oozes out.
(*b*) Ozone hole is a hole formed in the troposphere from which ozone oozes out.
(*c*) Ozone hole is thinning of ozone layer of stratosphere at some places.
(*d*) Ozone hole means vanishing of ozone layer around the earth completely.

12. Which of the following practices will **not** come under green chemistry?
(*a*) If possible, making use of soap made of vegetable oils instead of using synthetic detergents.
(*b*) Using H_2O_2 for bleaching purpose instead of using chlorine based bleaching agents.
(*c*) Using bicycle for travelling small distances instead of using petrol/diesel based vehicles.
(*d*) Using plastic cans for neatly storing substances.

Answers

9. (*a*) **10.** (*d*) **11.** (*c*) **12.** (*d*)

Multiple Choice Questions (Type-II)

13. Which of the following conditions shows the polluted environment.
(*a*) pH of rain water is 5.6.
(*b*) amount of carbon dioxide in the atmosphere is 0.03%.
(*c*) biochemical oxygen demand 10 ppm.
(*d*) eutrophication.

14. Phosphate containing fertilisers cause water pollution. Addition of such compounds in water bodies causes ____ .
(*a*) enhanced growth of algae.
(*b*) decrease in amount of dissolved oxygen in water.
(*c*) deposition of calcium phosphate.
(*d*) increase in fish population.

15. The acids present in acid rain are _____ .
(*a*) Peroxyacetyl nitrate (*b*) H_2CO_3
(*c*) HNO_3 (*d*) H_2SO_4

16. The consequences of global warming may be ____ .
(*a*) increase in average temperature of the earth.
(*b*) melting of Himalayan Glaciers.
(*c*) increased biochemical oxygen demand.
(*d*) eutrophication.

Matching Type Questions

In the following questions more than one option of Column I and Column II may match.

17. Match the terms given in Column I with the compounds given in Column II.

Column I	*Column II*
(*i*) Acid rain	(*a*) $CHCl_2 - CHF_2$
(*ii*) Photochemical smog	(*b*) CO
(*iii*) Combination with haemoglobin	(*c*) CO_2
(*iv*) Depletion of ozone layer	(*d*) SO_2
	(*e*) Unsaturated hydrocarbons

18. Match the pollutant(s) in Column I with the effect(s) in Column II.

Column I	*Column II*
(*i*) Oxides of sulphur	(*a*) Global warming
(*ii*) Nitrogen dioxide	(*b*) Damage to kidney
(*iii*) Carbon dioxide	(*c*) 'Blue baby' syndrome
(*iv*) Nitrate in drinking water	(*d*) Respiratory diseases
(*v*) Lead	(*e*) Red haze in traffc and congested areas

Answers

13. (*c, d*) **14.** (*a, b*) **15.** (*b, c, d*) **16.** (*a, b*) **17.** (*i*) – (*c, d*); (*ii*) – (*e, d*); (*iii*) – (*b*); (*iv*) – (*a*)
18. (*i*) – (*d*); (*ii*) – (*e*); (*iii*) – (*a*); (*iv*) – (*c*), (*v*) – (*b*)

Competition File

19. Match the activity given in Column I with the type of pollution created by it given in Column II.

Column I (Activity)	*Column II* (Effect)
(*i*) Releasing gases to the atmosphere after burning waste material containing sulphur.	(*a*) Water pollution
(*ii*) Using carbamates as pesticides	(*b*) Photochemical smog, damage to plant life, corrosion to building material, induce breathing problems, water pollution
(*iii*) Using synthetic detergents for washing clothes	(*c*) Damaging ozone layer
(*iv*) Releasing gases produced by auto-mobiles and factories in the atmosphere.	(*d*) May cause nerve diseases in human.
(*v*) Using chlorofluoro-carbon compounds for cleaning computer parts	(*e*) Classical smog, acid rain, water pollution, induce breathing problems, damage to buildings, corrosion of metals.

20. Match the pollutants given in Column I with their effects given in Column II.

Column I	*Column II*
(*i*) Phosphate fertilisers in water	(*a*) BOD level of water increases
(*ii*) Methane in air	(*b*) Acid rain
(*iii*) Synthetic detergents in water	(*c*) Global warming
(*iv*) Nitrogen oxides in air	(*d*) Eutrophication

Assertion and Reason Type Questions

In the following questions a statement of Assertion (A) followed by a statement of Reason (R) is given. Choose the correct option out of the choices given below each question.

(*a*) Both A and R are correct and R is the correct explanation of A.
(*b*) Both A and R are correct but R is not the correct explanation of A.
(*c*) Both A and R are not correct.
(*d*) A is not correct but R is correct.

21. Assertion (A) : Green house effect was observed in houses used to grow plants and these are made of green glass.
Reason (R) : Green house name has been given because glass houses are made of green glass.

22. Assertion (A) : The pH of acid rain is less than 5.6.
Reason (R) : Carbon dioxide present in the atmosphere dissolves in rain water and forms carbonic acid.

23. Assertion (A) : Photochemical smog is oxidising in nature.
Reason (R) : Photochemical smog contains NO_2 and O_3, which are formed during the sequence of reactions.

24. Assertion (A) : Carbon dioxide is one of the important greenhouse gases.
Reason (R) : It is largely produced by respiratory function of animals and plants.

25. Assertion (A) : Ozone is destroyed by solar radiation in upper stratosphere.
Reason (R) : Thinning of the ozone layer allows excessive UV radiations to reach the surface of earth.

26. Assertion (A) : Excessive use of chlorinated synthetic pesticides causes soil and water pollution.
Reason (R) : Such pesticides are non-biodegradable.

27. Assertion (A) : If BOD level of water in a reservoir is less than 5 ppm it is highly polluted.
Reason (R) : High biological oxygen demand means low activity of bacteria in water.

Answers

19. (*i*) – (*e*); (*ii*) – (*d*); (*iii*) – (*a*); (*iv*) – (*b*); (*v*) – (*c*) **20.** (*i*) – (*a, d*); (*ii*) – (*c*); (*iii*) – (*a*); (*iv*) – (*b*) **21.** (*c*) **22.** (*b*) **23.** (*a*) **24.** (*b*) **25.** (*d*) **26.** (*a*) **27.** (*c*)

Hints & Explanations for *Difficult Objective Type Questions*

B1. (*a*) : Ozone is depleted by chlorofluorocarbons (CF_2Cl_2).

B2. (*d*) : Chlorofluorocarbons known as freons deplete ozone layer.

B6.(*b*) : Fish dies in water bodies polluted by sewage or other pollutants due to decrease in dissolved oxygen (D.O.) value below 6 ppm.

B7.(*a*) : Excess nitrate in drinking water can cause methemoglobinemia (blue baby syndrome).

B8. (*d*) : Nitrogen is not a greenhouse gas.

B11. (*d*) : Chlorofluorocarbons are not a common component of photochemical smong.

B12. (*a*) : Microorganisms present in the soil is the sink of CO.

B13. (*a*) : N_2O_5 is not a common pollutant.

B16. (*b*) : Ozone layer is formed in the atmosphere by the decomposition of oxgen by ultra-violet radiation.

B20. (*c*) : D.D.T. is non-biodegradable pollutant.

Competition File

B21. (*b*) : The gas leaked in Bhopal gas tragedy was methylisocyanate ($CH_3N = C = O$).

B23. (*d*) : O_2 is not a greenhouse gas.

B26. (*c*) : The permissible limit of nitrate in water is about 50 ppm. Hence the concentration of NO_3^- ions in a given water sample exceeds from the permissible limit. The higher concentration of NO_3^- ions in water may cause blue baby syndrome disease.

B28. (*c*) : The F^- ion concentration is above the permissible limit in drinking water. Therefore, it is unsuitable for drinking. Excess concentration of F^- ions (greater than 2 ppm) causes brown mottling of teeth enamel.

B31. (*c*) : F^- ions make the teeth enamel harder by converting

$3Ca_3(PO_4)_2.Ca(OH)_2 \longrightarrow 3Ca_3(PO_4)_2.CaF_2$

B32. (*d*) : NO, O_3 and HCHO are involved in the formation of photochemical smog. N_2 has no role in photochemical smog.

B33. (*a*) : Clean water would have BOD value < 5ppm while BOD value of > 17 indicates highly polluted water.

NCERT Exemplar Problems : MCQs Type-I

3. (*a*) : Classical smog is not produced by the action of sunlight on emissions of automobiles and factories.

5. (*a*) : Ozone is also one of the greenhouse gas.

6. (*c*) : Organic waste consumes oxygen and therefore, dissolved oxygen in water decreases and fish in such polluted water die.

7. (*b*) : Photochemical smog is oxidising in nature because it contains large concentration of oxidising agents such as O_3 and NO_2.

10. (*d*) : Peroxyacetyl nitrate is a secondary pollutant which is formed from primary pollutants such as NO_2, O_3 and hydrocarbons.

NCERT Exemplar Problems : MCQs Type-II

15. (*b, c, d*) : The acids present in acid rain are H_2CO_3, HNO_3 and H_2SO_4.

16. (*a, b*) : The global warming may result into increase in average temperature of the earth and melting of Himalayan glaciers.

Unit Practice Test

for Board Examination

Time Allowed: 1 Hr. ***Maximum Marks: 25***

1.	Fish do not grow as well in warm water as in cold water. Why?	(1)
2.	What do the abbreviations 'BOD' and 'COD' stand for ?	(1)
3.	What are herbicides? Give one example.	(1)
4.	What is the major cause of ozone layer destruction?	(1)
5.	Name the gas which caused Bhopal gas tragedy?	(1)
6.	What is pneumoconiosis? How does it occur?	(2)
7.	Why does rain water normally have a pH of about 5.6 ? When does it become acidic rain?	(2)
8.	How can domestic waste be used as manure?	(2)
9.	Statues and monuments in India are affected by acid rain. How?	(2)
10.	List main differences between classical smog and photochemical smog.	(3)
11.	Give a brief account of green chemistry.	(3)
12.	Explain (*i*) Green house effect (*ii*) Tropospheric pollution.	(3)
13.	What are the reactions involved in ozone layer depletion in stratosphere ? What are its consequences ?	(3)

To check your performance, see HINTS and SOLUTIONS to some questions at the end of Part II of the book.

Test Your

Learning Ability

According to Completely CBSE Pattern

MOCK TEST – 2

Time allowed : 3 hours ***Maximum Marks : 70***

General Instructions :

(*i*) *All questions are compulsory.*

(*ii*) *Question nos. 1 to 5 are very short answer questions and carry 1 mark each.*

(*iii*) *Question nos. 6 to 12 are short answer questions and carry 2 marks each.*

(*iv*) *Question 13 to 24 are also short answer questions and carry 3 marks each.*

(*v*) *Question nos. 25 to 27 are long answer questions and carry 5 marks each.*

(*vi*) *Use log tables if necessary. Use of calculators in not allowed.*

Chapters Included :

8. Redox Reactions
9. Hydrogen
10. *s*-Block Elements (Alkali and Alkaline Earth Metals)
11. Some p-Block Elements
12. Organic Chemistry : Some Basic Principles and Techniques
13. Hydrocarbons
14. Environmental Pollution

1. Name the compound formed by the oxidation of ethyl benzene by $KMnO_4$. (1)

2. Which of the following is acidic?

(*i*) But-1-yne (*ii*) But-2-yne (*iii*) But-1-ene (*iv*) But-2-ene (1)

3. Compare the behaviour of CCl_4 and BCl_3 with water. (1)

4. Which out of lithium or sodium forms nitrides? (1)

5. Name a compound which retards the decomposition of H_2O_2. (1)

6. Give two examples each of ionic hydrides and covalent hydrides. (2)

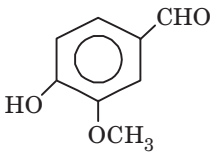
7. Why is Li_2CO_3 decomposed at a lower temperature while Na_2CO_3 is decomposed at higher temperature? (2)

8. Explain the higher stability of BCl_3 as compared to $TlCl_3$. (2)

9. Give condensed and bond line structural formulae for the following :

(*i*) 2-(4-isobutylphenyl) propanoic acid (*ii*) Hexanedial (2)

10. Write the IUPAC names of the following compounds :

(*i*) $(CH_3)_2C(C_2H_5)_2$ (*ii*) 

(2)

11. What is acid rain? What are its harmful effects? (2)

12. What is salt bridge? Give its functions. (2)

13. 0.35 g of an organic substance was Kjeldahlised and ammonia obtained was passed into 100 mL of $\frac{N}{10}$ H_2SO_4. The excess acid required 154 mL of $\frac{N}{10}$ NaOH for neutralisation. Calculate the percentage of nitrogen in the compound. (3)

14. Give one method of preparation of each of the following :

(*i*) Ethane

(*ii*) Propyne

(*iii*) Ethene (3)

15. Write short notes on the following :

(*a*) Wurtz reaction

(*b*) Markovnikov's rule

(*c*) Friedel Craft reaction (3)

16. What do you mean by green chemistry? How will it help decrease environmental pollution? (3)

17. Give the chemistry of Lassaigne's test for nitrogen and halogens. (3)

18. Complete the following reactions :

(*i*) $CH_3—C\equiv C—Ph \xrightarrow{Hg^{2+},\ H^+}$ (*ii*) $(CH_3)_2C=CH_2 \xrightarrow{Br_2,\ H_2O}$

(*iii*) $CH_3CH_2C(CH_3)=CHCH_3 \xrightarrow[Zn,\ H_2O]{O_3,}$ (3)

19. Write the structures and IUPAC names of different structural isomers of alkenes corresponding to the formula C_5H_{10}. (3)

20. Explain the following reactions :

(*i*) CO is heated with ZnO.

(*ii*) Hydrated alumina is heated with aqueous NaOH.

(*iii*) Silicon is heated with methyl chloride at high temperature in the presence of copper. (3)

21. Explain the following :

(*a*) Boric acid is polymeric

(*b*) Lead (IV) chloride is highly unstable towards heat.

(*c*) Graphite is used as a lubricant. (3)

22. (*a*) Why do alkenes under go electrophilic addition reactions? Give one example.

(*b*) An organic compound 'X' on ozonolysis gives a mixture of ethanal and pentan-3-one. Write structure and IUPAC name of 'X'. (3)

23. (*a*) What is meant by disproportionation reaction? Give one example.

(*b*) Balance the following redox reactions :

(*i*) $Br_2 + H_2O_2 \longrightarrow BrO_3^- + H_2O$ (acidic medium)

(*ii*) $P(s) + OH^-(aq) \longrightarrow PH_3(g) + H_2PO_2^-(aq)$ (3)

24. (*a*) Write down the chemical reactions involved during the formation of photochemical smog.

(*b*) Which out of CO or CO_2 is more dangerous pollutant? (3)

25. (*a*) What is diagonal relationship? How does lithium resemble magnesium?

(*b*) Explain the structure of diborane.

(*c*) Give three important uses of aluminium.

(*d*) $N(CH_3)_3$ is pyramidal but $N(SiH_3)_3$ is planar. Explain.

(*e*) Like CO why its analogue SiO is not stable. (5)

Or

(*a*) What are fullerenes? Discuss their structures.

(*b*) What are silicones? How are they prepared? Give their important uses.

26. (*a*) Describe Carius method for the estimation of halogens.

(*b*) What is the difference between distillation and fractional distillation.

(*c*) What is the structure of a carbanion? Explain the stability of CH_3^-, 1°, 2° and 3° carbanions. (5)

Or

Give a brief account of the following;

(*i*) hyperconjugation (*ii*) inductive effect (*iii*) electromeric effect

27. (*a*) Account for the acidity of alkynes.

(*b*) Explain the mechanism of sulphonation of benzene.

(*c*) How will you convert the following :

(*i*) Ethyne to but-2-yne (*ii*) Propene to 2, 3-dimethylbutane (*iii*) Ethene to ethyne. (5)

Or

(*a*) Explain the orbital picture of benzene.

(*b*) Give three methods of preparation of benzene.

According to Completely CBSE Pattern

MOCK TEST – 3

Time allowed : 3 hours ***Maximum Marks : 70***

General Instructions :

(*i*) *All questions are compulsory.*
(*ii*) *Question nos. 1 to 5 are very short answer questions and carry 1 mark each.*
(*iii*) *Question nos. 6 to 12 are short answer questions and carry 2 marks each.*
(*iv*) *Question 13 to 24 are also short answer questions and carry 3 marks each.*
(*v*) *Question nos. 25 to 27 are long answer questions and carry 5 marks each.*
(*vi*) *Use log tables if necessary. Use of calculators in not allowed.*

COMPLETE SYLLABUS

1. An aqueous solution of sodium carbonate gives alkaline tests. Why? (1)

2. What is the oxidation state of S in $Na_2S_2O_3$? (1)

3. What will be the pH of a 0.1 M ammonium acetate if $pK_a = pK_b = 4.74$? (1)

4. Write the conjugate acids of C_6H_5OH and NH_2NH_2. (1)

5. The equilibrium constant of a reaction at 27°C and 127° C are 1.52×10^{-4} and 1.26×10^{-2} respectively. Is the reaction exothermic or endothermic? (1)

6. Give molecular electronic configuration of peroxide ion and oxygen molecule. Which of the two has larger bond length? (2)

7. How would you explain the fact that the first ionization enthalpy of sodium is lower than that of magnesium but its second ionization enthalpy is higher than that of magnesium? (2)

8. Calculate the wavelength of an electron having mass = 9.1×10^{-31} kg and kinetic energy = 3.0×10^{25} J. (2)

9. If 20.0 g of $CaCO_3$ is treated with 20.0 g of HCl, how many grams of CO_2 can be produced according to the reaction :

$$CaCO_3(s) + 2HCl\,(aq) \longrightarrow CaCl_2\,(aq) + H_2O(l) + CO_2(g)$$ (2)

10. For the water gas reaction :

$$C(s) + H_2O\,(g) \longrightarrow CO(g) + H_2(g)$$

the standard Gibbs energy for the reaction at 1000K is –8.1 kJ mol^{-1}. Calculate its equilibrium constant. (2)

11. What is the relation between kinetic energy and temperature? (2)

12. Describe the shapes of BF_3 and BH_4^- and assign the hybridisation of boron in these species. (2)

13. Draw structures of cyclic and acylic isomers of molecular formula C_3H_6O. (3)

14. (*a*) Which of the two : $O_2N\,CH_2\,CH_2O^-$ or $CH_3\,CH_2O^-$ is expected to be more stable and why?

(*b*) Why alkyl groups act as electron donors when attached to a π-system.

(*c*) Which of the following carbocation is more stable :

(*i*) $(CH_3)_3CCH_2^+$ (*ii*) $CH_3\overset{+}{C}HCH_2CH_3$ (*iii*) $CH_3CH_2CH_2^+$ (3)

15. How will you convert :

(*i*) Ethane to butane (*ii*) Ethane to ethyne (*iii*) Ethyne to methane (3)

16. (*a*) Write down the products of ozonolysis of 1, 2-dimethylbenzene (o-xylene). How do the results support the Kekule structure of benzene?

(*b*) Why is benzene extra ordinarily stable though it contains three double bonds? (3)

17. Give the reasons :

(*i*) Aluminium wires are used to make transmission cables.

(*ii*) Diamond is used as an abrasive.

(*iii*) Aluminium utensils should not be kept in water overnight. (3)

18. Complete the following reactions :

(*i*) $Ca_3N_2(s) + H_2O(l) \longrightarrow$ (*ii*) $MnO_4^- + H^+ + H_2O_2 \longrightarrow$ (*iii*) $I_2 + H_2O_2 + OH^- \longrightarrow$ (3)

19. (*a*) The Mn^{3+} ion is unstable in solution and undergoes disproportionation to give Mn^{2+}, MnO_2, and H^+ ion. Write a balanced ionic equation for the reaction.

(*b*) Predict the product of electrolysis of an aqueous solution of $AgNO_3$ with Ag electrodes. (3)

20. (*a*) The wavelength of first spectral line in the Balmer series is 6561 Å. Calculate the wavelength of the second spectral line in Balmer series.

(*b*) How many electrons in a given atom can have the following quantum number values :

$n = 4, l = 2, m = \pm 1$ (3)

21. Commercially available sulphuric acid contains 93% acid by mass and has a density of 1.84 g mL^{-1}. Calculate (*i*) the molarity of the solution (*ii*) volume of concentrated acid required to prepare 2.5 L of 0.50 M H_2SO_4. (3)

22. (*a*) Define the following

(*i*) enthalpy of combustion (*ii*) enthalpy of formation

(*b*) The enthalpy change for the reaction :

$2NH_3(g) \longrightarrow N_2(g) + 3H_2(g)$

is 92.2 kJ. What is the enthalpy of formation of ammonia? (3)

23. (*a*) Name two phenomena which can be explained as the basis of surface tension.

(*b*) What is compressibility factor? How does it help to account for the nature of the gas? (3)

24. (*a*) Calculate the strength in volumes of a solution containing 30.36 g/L of H_2O_2.

(*b*) Complete the following reactions:

(*i*) $CaOCl_2 + H_2O_2 \longrightarrow$ (*ii*) $Fe_2(SO_4)_3 + H_2O_2 + NaOH \longrightarrow$ (3)

25. (*a*) On the basis of VSEPR theory, explain the shapes of following :

H_2O and NH_3 molecules.

(*b*) Draw resonance structures for SO_3 and CO_2 molecules.

(*c*) Which out of NH_3 and NF_3 has higher dipole moment and why ? (5)

Or

(*a*) Explain the structures of the following molecules on the basis of hybridisation.

(*i*) PF_5 (*ii*) BrF_5 (*iii*) XeF_4

(*b*) Ice floats over water. Explain.

(*c*) Out of MgO and LiCl, which has higher lattice enthalpy?

26. (*a*) What is solubility product? How is it different from ionic product.

(*b*) Calculate the molar solubility of $Ni(OH)_2$ in 0.10 M NaOH.

K_{sp} of $Ni(OH)_2 = 2.0 \times 10^{-15}$.

(*c*) What are acidic buffers? Give one example.

(*d*) Calculate the pH of 10^{-8} M HCl solution. (5)

Or

(*a*) How will you show that in a reversible reaction, equilibrium can be achieved from either direction?

(*b*) What is Le Chatelier's principle. With the help of this explain : ice melts when pressure is applied on it.

(*c*) Calculate the pH of a solution obtained by mixing 10 mL of 0.1 M HCl and 40 mL of 0.2 M H_2SO_4.

27. (*a*) Assign structures for the following :

(*i*) An alkyne (X) has molecular formula C_5H_8. It reacts neither with sodamide nor with ammoniacal cuprous chloride.

(*ii*) A hydrocarbon 'Y' decolourises bromine water. On ozonolysis it gives 3-methyl butanal and formaldehyde. Give the name of the compound.

(*iii*) A hydrocarbon (Z) has molecular formula C_8H_{10}. It does not decolourise bromine water and is oxidised to benzoic acid on heating with $K_2Cr_2O_7$. It can also have three other isomers A, B and C. Write the structures of Z, A, B and C.

(*b*) What effect does branching of an alkane chain has on its boiling point?

(*c*) Draw *cis* and *trans* isomers of hex-2-ene. Which isomer will have higher boiling point? (5)

Or

(*a*) Give the basic difference between Duma's method and Kjeldahl's method for the estimation of nitrogen.

(*b*) How will you convert:

(*i*) Acetylene to but-1-yne (*ii*) Propene to propan-1-ol (*iii*) ethanoic acid to ethane

(*c*) Suggest a suitable technique for the separation of naphthalene from kerosene present in a mixture.

Solution File

Hints & Solutions for *Unit Practice Tests & Mock Tests*

UNIT PRACTICE TEST–8

1. +6 because there is one peroxide bond (–O–O–) *i.e.*, O_2^{2-}
2. Oxidising agent : Cu^{2+}, reducing agent : I^-.
3. Na_2O_2 (–1), OF_2(+2)
4. The reaction in which an element in one oxidation state is simultaneously oxidised and reduced.
5. No, because the oxidation number of Cr has neither increased nor decreased but remains +6.
6. Since reduction potential of silver is more than that of hydrogen ($E^\circ_{H^+|H_2}$, Pt = 0), silver vessel will be suitable to store 1M HCl. On ther other hand, $E^\circ_{Al^{3+}|Al}$ is less than that of hydrogen ($E^\circ_{H^+|H_2}$, Pt) so that hydrogen will be liberated if stored in aluminium vessel.
7. (*i*) $\overset{+3\ -2}{Fe_2O_3} + 3\overset{+2\ -2}{CO} \longrightarrow 2\overset{0}{Fe}(s) + 3\overset{+4\ -2}{CO_2}$

   O.N. of Fe decreases from +3 (in Fe_2O_3) to 0 (in Fe) and that of C increases from +2 (in CO) to +4 (in CO_2). Therefore, Fe_2O_3 is reduced while CO is oxidised. Thus, this is a redox reaction.

   (*ii*) $4\overset{-3\ +1}{NH_3}(g) + 5\overset{0}{O_2}(g) \longrightarrow 4\overset{+2\ -2}{NO}(g) + 6\overset{+1\ -2}{H_2O}(g)$

   In this case O.N. of N increases from –3 (in NH_3) to +2 (in NO) and that of O decreases from 0 (in O_2) to –2 (in H_2O). Therefore, NH_3 has been oxidised while O_2 has been reduced. Hence, it is a redox reaction.
8. In AgF_2, oxidation state of Ag is +2 which is very unstable. Therefore, it readily accepts an electron to form a more stable oxidation state of +1 as

   $$Ag^{2+} + e^- \longrightarrow Ag^+$$

   Therefore, AgF_2 if formed will act as a strong oxidising agent.
9. The O.S. of S in $S_2O_3^{2-}$ is +2, in $S_4O_6^{2-}$ it is +2.5 (average) and in SO_4^{2-} it is +6. Since Br_2 is a stronger oxidising agent than I_2, it oxidises S of $S_2O_3^{2-}$ to SO_4^{2-} (with higher O.S. of +6). However, I_2 being a weaker oxidising agent, it oxidises S of $S_2O_3^{2-}$ into a lower O.S. of +2.5 in $S_4O_6^{2-}$. Therefore, $S_2O_3^{2-}$ reacts differently with Br_2 and I_2.
10. The cell may be depicted similar to Fig. 3. It may be represented as :

    $$Zn(s) \mid Zn^{2+}(aq) \parallel Ag^+(aq) \mid Ag$$

    (*i*) Zinc electrode (anode)

    (*ii*) At anode : $Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^-$

    At cathode : $Ag^+(aq) + e^- \longrightarrow Ag(s)$
11. *Refer Solved Example 30*
12. *Refer Solved Example 20 (ii) and (iv).*
13. *Refer Solved NCERT Exercise, Q.4 and 5.*

UNIT PRACTICE TEST–9

1. Perhydrol
2. Conc. H_2SO_4 on absorbing water from moist H_2 produces so much heat that H_2 catches fire.
3. Deuteroacetylene is formed :

   $$CaC_2 + D_2O \longrightarrow Ca(OD)_2 + C_2D_2$$
4. 1 : 2 : 3
5. Heavy water is injurious to plants, animals and human beings because it slows down the rates of reactions occurring in them. So, it cannot be used.
6. *Refer NCERT File Q. 24.*
8. $2H_2O_2 \longrightarrow 2H_2O + O_2$

   68 g 22.4L at N.T.P.

   22.4L of O_2 at N.T.P. is produced from H_2O_2 = 68 g

   25 L of O_2 at N.T.P. is produced from H_2O_2

   $$= \frac{68}{22.4} \times 25 = 75.9 \text{ g}$$

   Strength of 25 volume H_2O_2 = 75.9 g/L

   Amount of H_2O_2 present in 10 mL = $\frac{75.9}{1000} \times 10$

   = 0.759 g.
9. *Refer NCERT File Q. 7.*
10. *Refer NCERT File Q. 8.*
11. (*a*) $Zn(s) + 2NaOH(aq) \longrightarrow \underset{\text{Sod. zincate}}{Na_2ZnO_2(aq)} + H_2(g)$

    (*b*) $4LiH + AlCl_3 \longrightarrow LiAlH_4 + 3\,HCl$

    (*c*) $Ca_3N_2 + 6H_2O \longrightarrow 3Ca(OH)_2 + 2NH_3$

UNIT PRACTICE TEST–10

1. Francium and radium
2. Both Li^+ and H^- have small size and their combination has high lattice energy. Therefore, LiH is stable as compared to NaH.
3. Lithium
4. C_6H_6
5. +1
6. Potassium carbonate cannot be prepared by Solvay process because potassium bicarbonate being more soluble than sodium bicarbonate does not get precipitated when CO_2 is passed through a concentrated solution of KCl saturated with NH_3.
7. Beryllium and magnesium atoms in comparison to other alkaline earth metals are comparatively smaller and their ionisation enthalpies are very high. Hence,

Solution File

the energy of the flame is not sufficient to excite their electrons to higher energy levels. These elements, therefore, do not give any colour in Bunsen flame.

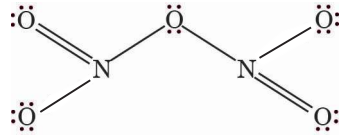
8. *Refer NCERT File Q. 19.*
9. *Refer NCERT File Q. 27. (c) and (b)*
10. *Refer NCERT File Q. 15.*
12. (*a*) *Refer Solved Example 7*
    (*b*) Lithium ion is very small ion and therefore, it has strong positive field around it. Therefore, it can stabilize only a small anion O^{2-}. Sodium is large and it can stabilize large anion O_2^{2-} whereas potassium and rubidium being very large in size can easily stabilize larger superoxide O_2^- ion.
    (*c*) *Refer NCERT File Q.29 (ii).*
13. (*a*) $Rb^+ > K^+ > Na^+ > Li^+$ because of lesser hydration of ion as size increases. In other words, hydrated radii of ions decrease as Li^+ , Na^+, K^+, Rb^+.
    (*b*) *Refer NCERT File Q.12.*

UNIT PRACTICE TEST–11

1. $SiCl_4$
2. Due to inert pair effect, lead shows an oxidation state of +2 and therefore, $PbCl_2$ is more stable than $PbCl_4$.
3. Six
4. $:\ddot{O}{=}C{=}\ddot{O}: \longleftrightarrow :\overset{+}{O}{\equiv}C{-}\overset{-}{\ddot{O}}: \longleftrightarrow :\overset{-}{\ddot{O}}{-}C{\equiv}\overset{+}{O}:$
5. Boric acid is not a protic acid because it does not ionise in water to give a proton. But it acts as a Lewis acid by accepting electrons from hydroxide ion.
   $B(OH)_3 + H_2O \longrightarrow [B(OH)_4]^- + H_3O^+$
6. *Refer NCERT File Q. 14.*
7. *Refer NCERT File Q. 3.*
8. *Refer NCERT File Q. 24.*
9. (*i*) *Refer Conceptual Questions* 2 *Q. 1.*
   (*ii*) *Refer Conceptual Questions* 2 *Q. 2.*
   (*iii*) *Refer Solved Example 25.*
10. *Refer NCERT File Q. 28.*
11. (*i*) $BCl_3 + 3H_2O \longrightarrow H_3BO_3 + 6HCl$
    (*ii*) $SiF_4 + 2HF \longrightarrow H_2SiF_6$
    (*iii*) $ZnO + CO \longrightarrow Zn + CO_2$
    (*iv*) $Al_2O_3.\ 2H_2O(l) + 2NaOH(aq) + H_2O(l) \longrightarrow 2Na[Al(OH)_4](aq)$
    (*v*) $Pb + 2NaOH + 4H_2O \longrightarrow Na_2\ [Pb(OH)_6] + 2H_2$
    (*vi*) $2NaH + B_2H_6 \longrightarrow 2Na\ [BH_4]$

UNIT PRACTICE TEST–11A

1. N_2O_5 has the structure



   The covalence of N is four because it has four shared pair of electrons.
2. $4\overset{+3}{H_3}\overset{+5}{P}O_3 \longrightarrow 2H_3\overset{+5}{P}O_4 + \overset{-3}{P}H_3$
3. $3CuO + 2NH_3 \xrightarrow{heat} 3Cu + N_2 + 3H_2O$
4. Phosphine is formed :
   $P_4 + 3NaOH + 3H_2O \xrightarrow{Heat} PH_3 + 3NaH_2PO_2$
5. Due to small size of Cl atom, five Cl atoms can be accommodated around P atom. But I is of large size and therefore, five I atoms cannot be accommodated around P atom. As a result, P–I bonds are weak and prefer to form PI_3 rather than PI_5.
7. Refer Text Fig. 16 and Fig. 17 page 11A/30.
8. (*i*) Both PCl_5 and PBr_5 have trigonal bipyramidal geometry. This is not regular structure and is not stable. Therefore, PCl_5 splits into more stable octahedral and tetrahedral structures.

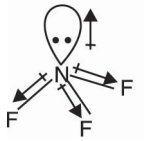
$$2PCl_5 \rightleftharpoons \underset{\text{Tetrahedral}}{[PCl_4]^+} \quad \underset{\text{Octohedral}}{[PCl_6]^-}$$

But PBr_5 splits up into more stable tetrahedral structure.

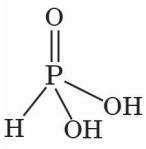
$$PB_5 \rightleftharpoons [PBr_4]^+\ [Br]^-$$

Since Br atoms are large, these six Br atoms cannot be accommodated around P atom to form octahedral structure.

(*ii*) In NF_3, the lone pair on N atom is on the opposite direction to N–F bond moments and therefore, it does not have donor properties like NH_3.



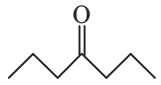
10. (*iii*) H_3PO_3 contains two P—OH bonds and therefore, its basicity is two.



12. (*i*) $XeF_6 + 3H_2O \longrightarrow XeO_3 + 6HF$
    (*ii*) $P_4O_{10} + 6H_2O \longrightarrow 4H_3PO_4$
    (*iii*) $2Ca_3(PO_4)_2 + 6SiO + 10C \longrightarrow P_4 + 6CaSiO_3 + 10CO$

Solution File

UNIT PRACTICE TEST–12

1. 

sp^3 sp^2 sp^2 sp

2. $CH_3—CH=CH—CN$
3. $(CH_3)_3C^+$
4. $Fe_4[Fe(CN)_6]_3$
5. $O_2NCH_2CH_2O^-$ is more stable because $–NO_2$ group has –I inductive effect and tends to disperse the –ve charge on the O atom. This results into stability. However, $CH_3CH_2^-$ group has +I inductive effect and tends to intensify the –ve charge and therefore, destabilizes it.
6. *Refer NCERT File Q. 11.*
7. AgCl ≡ Cl

   143.5 35.5

   143.5 g of AgCl contain Cl = 35.5

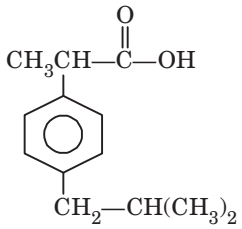
   0.628 g of AgCl contain Cl $= \frac{35.5}{143.5} \times 0.628$

   $= 0.155$ g

   % of chlorine $= \frac{0.155}{0.320} \times 100 = 48.43$ %
8. *Refer Solved Example 30.*
10. *Refer NCERT File Q. 20.*
11. (*i*) Pent-3-en-1-yne

    (*ii*) 4-(1,1-dimethylpropyl)-3-ethyl-4, 7-dimethyldecane

    (*iii*) 5, 6-Dimethylcyclohex-2-en-1-one
12. (*i*) $OHCCH_2CH_2CH_2CHO$

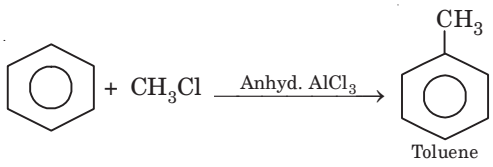
    (*ii*) 

    (*iii*) $CH_3CH=CHCOOH$
13. (*a*) *Refer NCERT File Q. 29.*

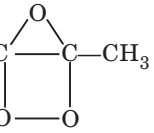
    (*b*) *Refer Conceptual Questions 2 Q. 9.*

    (*c*) *Refer NCERT File Q.10.*

UNIT PRACTICE TEST–13

1. $CH_3CH_2COOH + 6HI \longrightarrow \underset{\text{Propene}}{CH_3CH_2CH_3} + 2H_2O + 3I_2$
2. 2-Methylpentane
3. $CH_2=CH—CH=CH_2$: Penta-2, 4-diene
4. Yes, it will show geometrical isomerism.
5. Cyclopentadienyl cation.
6. *Refer Solved Example 30.*
7. *Refer Solved Example 46 (ii).*
8. *Refer NCERT File Q. 25.*
9. *Refer NCERT File Q. 16.*
10. (*i*) 

    Toluene

    (*ii*) $CH_3C\equiv CCH_3 \xrightarrow{O_3}$  $\xrightarrow{Zn, H_2O}$ $CH_3—\underset{\underset{O}{\|}}{C}—\underset{\underset{O}{\|}}{C}—CH_3$

    Butane-2, 3-dione

    (*iii*) $CH_3CH_2C\equiv CH \xrightarrow[\text{Heat}]{\text{acidic } KMnO_4} \underset{\text{Propanoic acid}}{CH_3CH_2COOH} + CO_2 + H_2O$
12. (*a*) *Refer Solved Example 28*

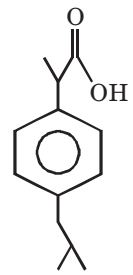
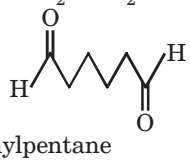
    (*b*) *Refer NCERT File Q.10.*

UNIT PRACTICE TEST–14

1. The amount of dissolved oxygen is less in warm water than in cold water.
2. Biological oxygen demand, chemical oxygen demand.
3. The chemical substances used to kill weeds or undesirable vegetation. *e.g.,* sodium arsenate.
4. Chlorofluorocarbon compounds.
5. Methyl isocyanate ($CH_3N=C=O$).
6. *Refer Conceptual Questions, Q.6.*
7. *Refer Conceptual Questions, Q.5.*
8. *Refer NCERT File Q. 19*
9. *Refer NCERT File Q. 5*
10. *Refer Conceptual Questions, Q. 10.*

❐❐❐

MOCK TEST – 2

1. benzoic acid
2. (*i*)
3. CCl_4 does not get hydrolysed while BCl_3 readily gets hydrolysed to boric acid.
   $BCl_3 + 3H_2O \longrightarrow H_3BO_3 + 6HCl$
4. Lithium
5. acetanilide
6. (*i*) LiH, CaH_2 : ionic hydrides
   (*ii*) NH_3, SiH_4 : covalent hydrides
7. Lithium is less electropositive than sodium and therefore, carbonate of lithium is less stable than that of sodium. Li_2CO_3 is not so stable to heat and therefore, decomposes at lower temperature. This is because lithium being very small in size polarises a large CO_3^{2-} ion leading to the formation of Li_2O and CO_2. On the other hand, Na_2CO_3 is very stable and decomposes at higher temperature.
8. *Refer Chapter 11 Conceptual Questions,* I *Q. 9*
9. (*i*) $CH_3—CH(COOH)—CH_2—CH(CH_3)—CH_3$ and 
   (*ii*) $OCH—CH_2—CH_2—CH_2—CH_2—CHO$ 
10. (*i*) 3, 3-Dimethylpentane
    (*ii*) 4-Hydroxy-3-methoxy benzaldehyde.
13. *Refer Chapter 12 Solved Example 36.*
18. (*i*) $CH_3—C\equiv C—Ph \xrightarrow[H_2O]{Hg^{2+},\ H^+} CH_3—CH=C(OH)—Ph \rightleftharpoons CH_3—CH_2—C(=O)—Ph$

(*ii*) $(CH_3)_2C=CH_2 \xrightarrow{Br_2,\ H_2O} CH_3—C(CH_3)(OH)—CH_2Br$

(*iii*) $CH_3CH_2C(CH_3)=CHCH_3 \xrightarrow[Zn,\ H_2O]{O_3,} CH_3CH_2—C(CH_3)=O + CH_3CHO$

19. *Refer Chapter 13 Solved Example 14.*
20. *Refer Chapter 11 Solved Example 20.*
22. (*b*) $CH_3CH=C(CH_2CH_3)_2$: 3-Ethylpent-2-ene
23. (*b*) *Refer NCERT File Chapter 13. Q. 1.*
24. (*b*) CO
27. (*c*) (*i*) $HC\equiv CH \xrightarrow{2\,NaNH_2} NaC\equiv CNa \xrightarrow{2CH_3Br} CH_3C\equiv CCH_3$
    Ethyne — But-2-yne

(*ii*) $CH_3CH=CH_2 \xrightarrow{HBr} CH_3CH(Br)CH_3 \xrightarrow[\text{Wurtz reaction}]{Na,\ ether} CH_3CH(CH_3)—CH(CH_3)—CH_3$
Propene — 2,3-Dimethyl butane

(*iii*) $CH_2=CH_2 \xrightarrow{Br_2,\ CCl_4} CH_2(Br)—CH_2(Br) \xrightarrow{2\ alc.\ KOH} HC\equiv CH$
Ethene — Ethyne

MOCK TEST – 3

1. In aqueous solution, sodium carbonate gets hydrolysed to give OH^- ions and hence it gives alkaline tests.

$$CO_3^{2-} + H_2O \longrightarrow HCO_3^- + OH^-$$

2. + 2.

3. $pH = \frac{1}{2}pK_w + \frac{1}{2}pK_a - \frac{1}{2}pK_b = 7$

4. $C_6H_5OH_2^+, NH_2NH_3^+$

5. endothermic

6. Peroxide ion has larger bond length.

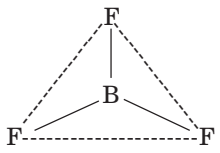
7. *Refer Conceptual Questions, Ch. 3. Q. 11.*

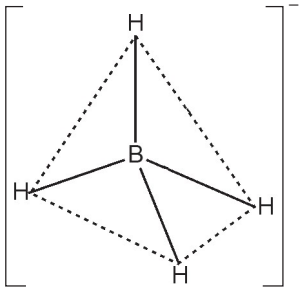
8. *Refer Chapter 2 Solved Example 53.*

9. *Refer Chapter 1 Solved Example 93.*

10.
$$\log K = -\frac{\Delta G^\circ}{2.303\,RT}$$
$$= -\frac{-8.1}{2.308 \times 8.314 \times 10^{-3} \times 1000}$$
$$= 0.423$$
$$\therefore \quad K = \mathbf{2.64}$$

12. BF_3 is trigonal planar having sp^2 hybridisation. BH_4^- is tetrahedral having sp^3 hybridisation.





13. *Refer Conceptual Questions Chapter 12. Q. 14.*

15. (*i*) $\underset{\text{Ethane}}{CH_3CH_3} \xrightarrow[h\nu]{Cl_2} CH_3CH_2Cl$

$$\xrightarrow[\text{Wurtz reaction}]{2Na,\ \text{ether}} \underset{\text{Butane}}{CH_3CH_2CH_2CH_3}$$

(*ii*) $\underset{\text{Ethane}}{CH_3CH_3} \xrightarrow[h\nu]{Cl_2} CH_3CH_2Cl \xrightarrow{\text{alc. KOH}}$

$$CH_2{=}CH_2 \xrightarrow{Br_2} \underset{Br}{\overset{|}{CH_2}}{-}\underset{Br}{\overset{|}{CH_2}}$$

$$\downarrow \text{2 alc. KOH}$$

$$\underset{\text{Ethyne}}{HC{\equiv}CH}$$

(*iii*) $HC{\equiv}CH \xrightarrow[Hg^{2+}]{H^+,\ H_2O} CH_3CHO \xrightarrow{O} CH_3COOH$

$$\xrightarrow{NaOH} CH_3COONa$$
$$\downarrow NaO,\ CaO$$
$$CH_4$$

16. *Refer NCERT File Chapter 13, Q. (a) 17 and (b) Q. 10.*

18. (*i*) $Ca_3N_2\,(s) + 3H_2O(l) \longrightarrow 3Ca(OH)_2 + 2NH_3$

(*ii*) $2MnO_4^- + 6H^+ + 5H_2O_2 \longrightarrow 2Mn^{2+} + 8H_2O + 5O_2$

(*iii*) $I_2 + H_2O_2 + 2OH^- \longrightarrow 2I^- + 2H_2O + O_2$

19. (*a*) *Refer Chapter 2 NCERT File Chapter 8, Q. 21.*

(*b*) *Refer NCERT File Chapter 8, Q. 27.*

20. (*a*) *Refer Chapter 2 Solved Example 39*

(*b*) 4

21. *Refer Chapter 1 Solved Example 119.*

22. (*b*) –46.1 kJ mol^{-1}

24. (*a*) 10 volumes

(*b*) (*i*) $CaOCl_2 + H_2O_2 \longrightarrow CaCl_2 + H_2O + O_2$

(*ii*) $Fe_2(SO_4)_3 + H_2O_2 + 2NaOH \longrightarrow 2FeSO_4 + Na_2SO_4 + O_2 + 2H_2O$

25. (*c*) MgO

26. (*b*) *Refer Chapter 7 Solved Example 103.*

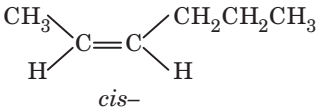
(*d*) *Refe Chapter 7 Solved Example 65.*

Or

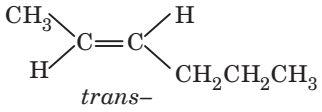
(*c*) 0.468

27. (*a*) *Refer Chapter 13 Solved Example 37.*

(*c*)



cis–



trans–

cis-hex-2-ene has higher dipole moment and therefore, will have stronger dipole–dipole interactions and hence higher boiling point.

❐❐❐

APPENDICES

C **ORGANIC CONVERSIONS**

D **WHAT HAPPENS WHEN ?**

E **SOME ORGANIC COMPOUNDS POPULARLY KNOWN BY THEIR COMMON NAMES**

Appendix C

ORGANIC CONVERSIONS

A : Aliphatic Compounds

How will you convert?

1. Methane to ethane
2. Methane to ethanoic acid
3. Ethane to ethene
4. Ethane to ethyne
5. Ethane to ethylene glycol
6. Acetylene to acetic acid
7. Ethene to ethyne
8. Ethyne to propyne
9. Ethene to bromoethene
10. Propane to ethene
11. Ethyne to 2-butyne
12. Ethyne to propanone
13. Ethanoic acid to ethane
14. Ethyne to methane
15. Ethene to methanal
16. Ethene to ethanal
17. Propene to 2, 3-dimethylbutane
18. Propene to 1-propanol
19. Ethyne to benzene
20. Propyne to 1, 1-dibromopropane
21. Ethyne to dichloroethanal
22. Ethyne to 1,2 - dibromoethane
23. Acetic acid to methane
24. Acetylene to acetone
25. Ethyne to oxalic acid
26. Acetylene to 1 - butyne
27. Ethene to methanoic acid
28. Propene to 1– bromopropane

B : Aromatic Compounds

How will you convert?

1. Benzene to acetophenone
2. Toluene to benzene
3. Benzene to benzoic acid
4. Benzene to maleic anhydride
5. Benzoic acid to benzene
6. Benzene to *m*–nitrotoluene
7. Benzene to benzene hexachloride
8. Benzene to benzaldehyde
9. Benzene to *m*-nitrobenzoic acid
10. Acetylene to cyclohexane

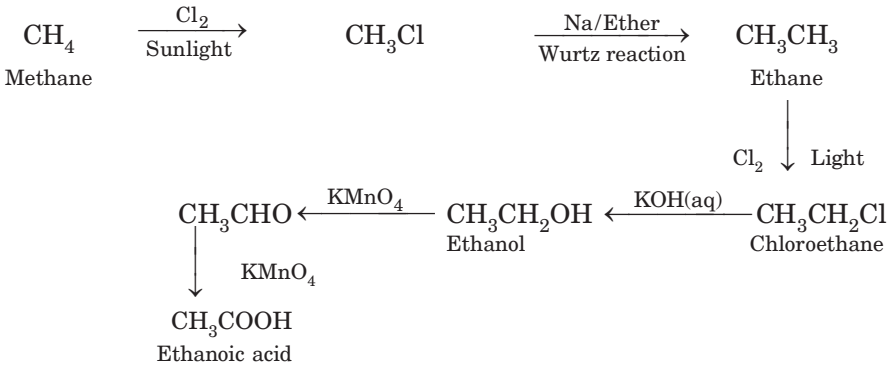
A : Answers

1. *Methane to ethane*

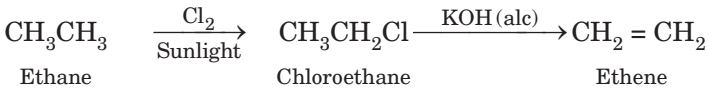
$$\underset{\text{Methane}}{CH_4} \xrightarrow[\text{Sunlight}]{Cl_2} \underset{\text{Chloromethane}}{CH_3Cl} \xrightarrow[\text{Wurtz reaction}]{\text{Na, Ether}} \underset{\text{Ethane}}{CH_3CH_3}$$

Appendices

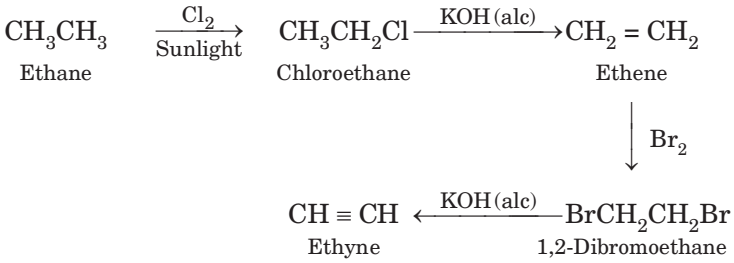
2. *Methane to ethanoic acid*



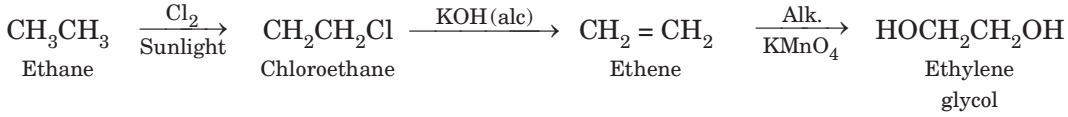
3. *Ethane to ethene*



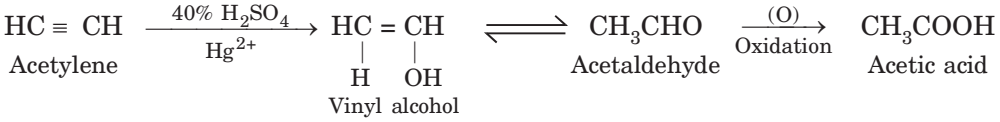
4. *Ethane to ethyne*



5. *Ethane to ethylene glycol*

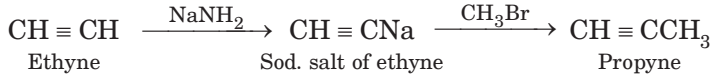


6. *Acetylene to acetic acid*

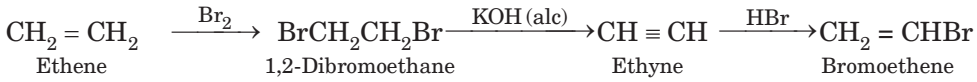


7. *Ethene to ethyne*

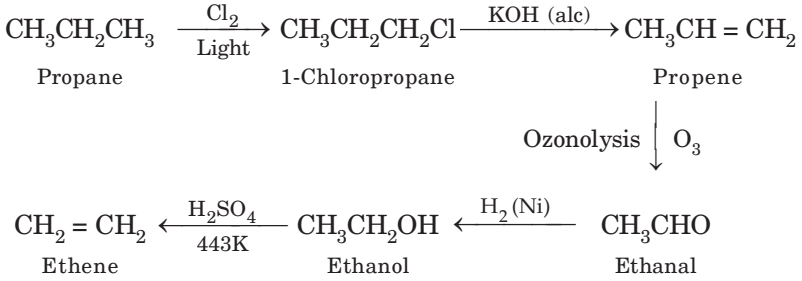
8. *Ethyne to propyne*



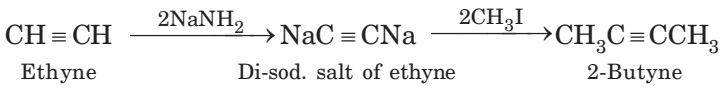
9. *Ethene to bromoethene*



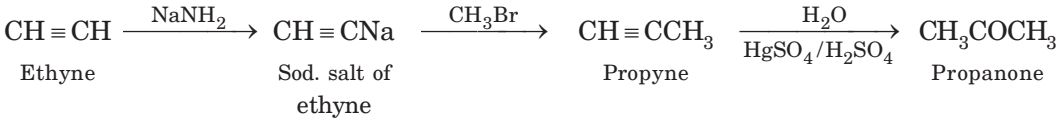
10. *Propane to ethene*



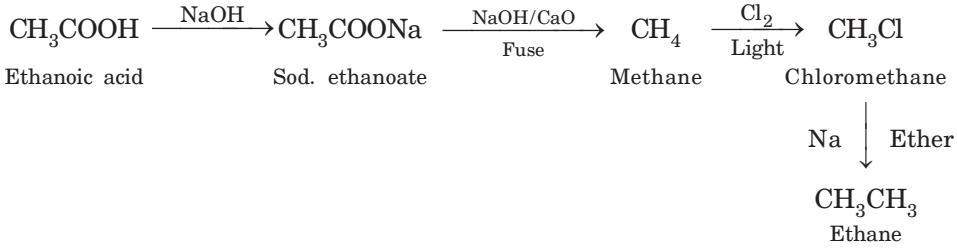
11. *Ethyne to 2-butyne*



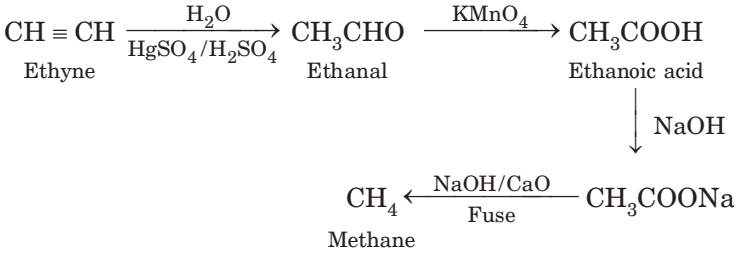
12. *Ethyne to propanone*



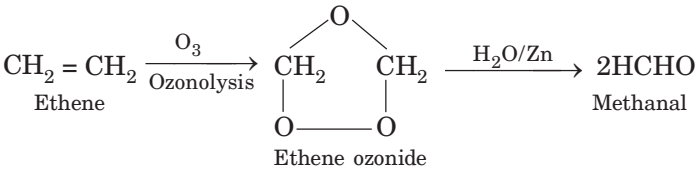
13. *Ethanoic acid to ethane*



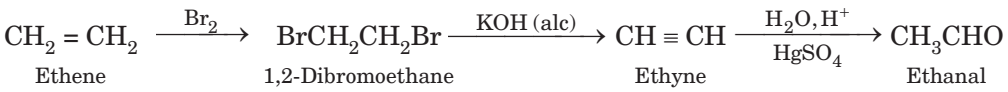
14. *Ethyne to methane*



15. *Ethene to methanal*



16. *Ethene to ethanal*



17. *Propene to 2,3-dimethylbutane*

$$\underset{\text{Propene}}{CH_3CH=CH_2} \xrightarrow{HBr} \underset{\text{2-Bromopropane}}{CH_3\overset{\overset{Br}{|}}{C}HCH_3} \xrightarrow[\text{Wurtz reaction}]{\text{Na/Ether}} \underset{\text{2,3-Dimethylbutane}}{CH_3-\overset{\overset{CH_3}{|}}{C}H-\overset{\overset{CH_3}{|}}{C}H-CH_3}$$

18. *Propene to 1-propanol*

$$\underset{\text{Propene}}{CH_3CH=CH_2} \xrightarrow[(R-O-O-R)]{HBr} \underset{\text{1-Bromopropane}}{CH_3CH_2CH_2Br} \xrightarrow{KOH\ (aq)} \underset{\text{1-Propanol}}{CH_3CH_2CH_2OH}$$

19. *Ethyne to benzene*

$$\underset{\text{Ethyne}}{3\ CH\equiv CH} \xrightarrow[\text{(Polymerisation)}]{\text{Copper tubes}} \underset{\text{Benzene}}{\text{  }}$$

20. *Propyne to 1, 1-dibromopropane*

$$\underset{\text{Propyne}}{CH_3C\equiv CH} \xrightarrow[(R-O-O-R)]{HBr} \underset{\text{1-Bromopropane}}{CH_3CH=CHBr} \xrightarrow[(R-O-O-R)]{HBr} \underset{\text{1,1-Dibromopropane}}{CH_3CH_2CHBr_2}$$

21. *Ethyne to dichloroethanal*

$$\underset{\text{Ethyne}}{CH\equiv CH} \xrightarrow{HClO} \underset{\text{Intermediate compound}}{[CH(OH)=CH(Cl)]} \xrightarrow{HClO} CH(OH)_2CHCl_2 \xrightarrow[\text{(Unstable)}]{H_2O} \underset{\text{Dichloroethanal}}{CHOCHCl_2}$$

22. *Ethyne to 1,2-dibromoethane*

$$\underset{\text{Ethyne}}{CH\equiv CH} \xrightarrow[Pd/BaSO_4]{H_2} \underset{\text{Ethene}}{CH_2=CH_2} \xrightarrow{Br_2} \underset{\text{1,2-Dibromoethane}}{CH_2BrCH_2Br}$$

23. *Acetic acid to methane*

$$\underset{\text{Acetic acid}}{CH_3COOH} \xrightarrow{NaOH} CH_3COONa \xrightarrow[CaO]{NaOH} \underset{\text{Methane}}{CH_4}$$

24. *Acetylene to acetone*

$$\underset{\text{Acetylene}}{HC\equiv CH} \xrightarrow{NaNH_2} HC\equiv CNa \xrightarrow{CH_3Cl} HC\equiv C-CH_3 \xrightarrow[HgSO_4]{\text{dil. } H_2SO_4} \underset{\text{Acetone}}{CH_3-\overset{\overset{O}{||}}{C}-CH_3}$$

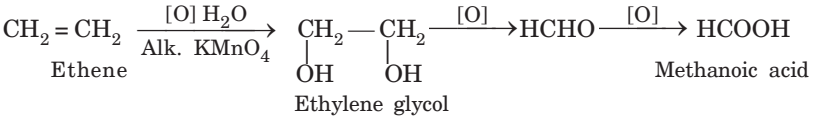
25. *Ethyne to oxalic acid*

$$\underset{\text{Ethyne}}{\overset{\overset{CH}{|||}}{CH}} \xrightarrow[\text{Alkaline } KMnO_4]{4[O]} \underset{\text{Oxalic acid}}{\overset{\overset{COOH}{||}}{COOH}}$$

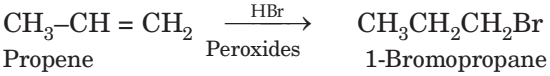
26. *Acetylene to 1 - Butyne*

$$\underset{\text{Ethyne}}{HC\equiv CH} \xrightarrow{NaNH_2} HC\equiv CNa \xrightarrow{CH_3CH_2Br} \underset{\text{1 – Butyne}}{HC\equiv C-CH_2\ CH_3}$$

27. *Ethene to methanoic acid*

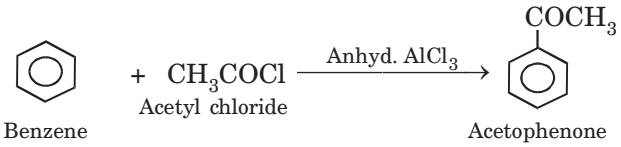


28. *Propene to 1– bromopropane*

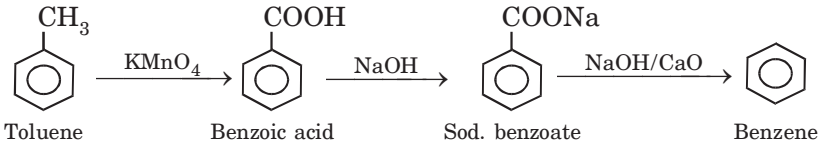


B : Answers

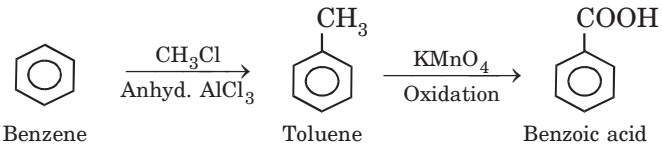
1. *Benzene to acetophenone*



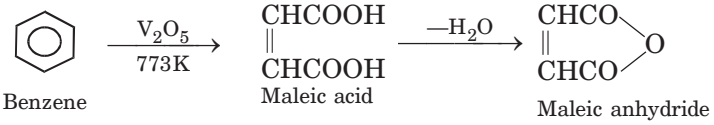
2. *Toluene to benzene*



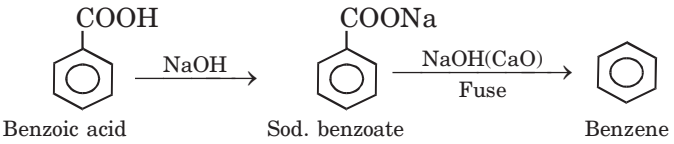
3. *Benzene to benzoic acid*



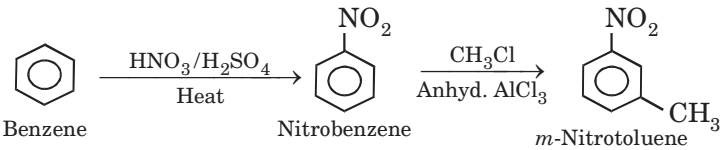
4. *Benzene to maleic anhydride*



5. *Benzoic acid to benzene*

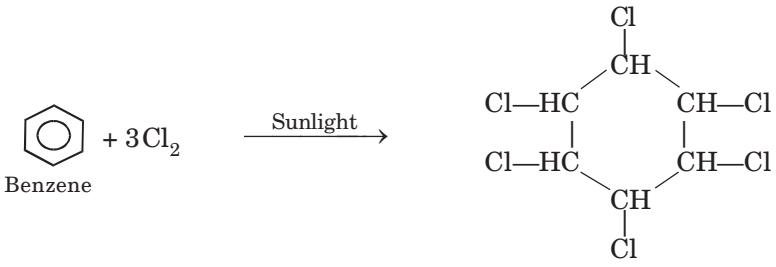


6. *Benzene to m-nitrotoluene*



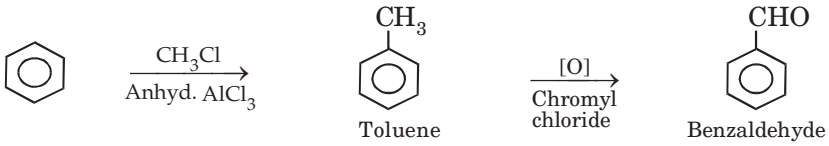
Appendices

7. *Benzene to benzene hexachloride*

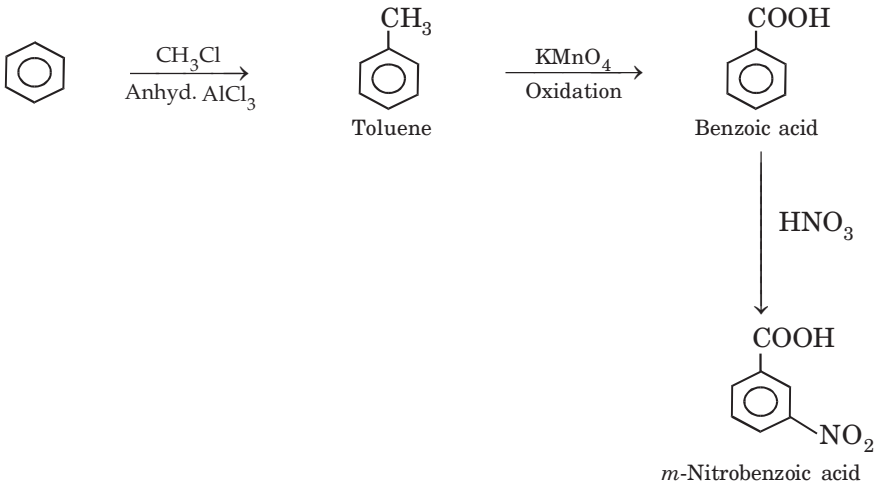


Benzene hexachloride (BHC)

8. *Benzene to benzaldehyde*

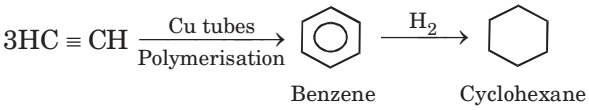


9. *Benzene to m-Nitrobenzoic acid*



m-Nitrobenzoic acid

10. *Acetylene to cyclohexane*



Appendix D

WHAT HAPPENS WHEN ?

1. Ethylene is passed through alkaline potassium permanganate solution.
2. 2-Butene is treated with ozone followed by zinc dust and acid.
3. Propene reacts with water in the presence of mineral acid.
4. Ethyl chloride is treated with alcoholic caustic potash.
5. Benzene is treated with methyl chloride in the presence of anhydrous aluminium chloride.
6. Ethyne is bubbled into ammoniacal solution of cuprous chloride.
7. Propene is treated with HBr in the presence of peroxides.
8. Water is dropped over calcium carbide.
9. Water is added on ethyl magnesium bromide.
10. Benzene is heated with mixture of conc. HNO_3 and conc. H_2SO_4.
11. Toluene is treated with hot solution of potassium permanganate.
12. Sodium acetate is heated with soda lime.
13. Ethyl iodide is reduced.
14. Acetylene is heated to 773 K in copper tubes.
15. Ethylene dibromide is treated with zinc dust.
16. Benzene is treated with Cl_2 in the presence of $FeCl_3$.
17. Ethylene is treated with ozone.
18. Benzene is treated with chlorine in the presence of sunlight and absence of halogen carrier.
19. An aqueous solution of sodium salt of succinic acid is electrolysed.
20. Methane is mixed with oxygen and passed through heated molybdenum oxide.
21. Solution of ethylene in carbon tetrachloride is treated with chlorine at room temperature.
22. Propene is treated with hydrogen in the presence of Ni or Pt.
23. Propene is treated with Baeyer's reagent.
24. Styrene is polymerised.
25. Ethene is treated with excess of oxygen.
26. Propylene is treated with excess bromine in CCl_4.
27. Ethyne is oxidised with alkaline $KMnO_4$.
28. Propyne is treated with water in the presence of sulphuric acid and mercuric sulphate.
29. Acetylene is treated with ammoniacal silver nitrate solution.
30. Benzene is treated with sulphuric acid in the presence of sulphur trioxide.
31. Benzene is treated with acetyl chloride in the presence of anhydrous aluminium chloride.
32. Benzene is treated with hydrogen in the presence of Ni or Pt at 473-573 K.
33. Toluene is oxidised with chromyl chloride.
34. 2-methyl -2-butene is treated with ozone followed by reduction with hydrogen in the presence of zinc.
35. Mixture of methane and oxygen is compressed to 120 atm and passed through copper tubes at 475 K.
36. Ethane is treated with nitric acid in vapour phase.

Answers

1. Pink colour of $KMnO_4$ solution gets discharged and ethylene glycol is formed.

$$\underset{\text{Ethylene}}{CH_2=CH_2} + H_2O + O \xrightarrow{KMnO_4} \underset{\text{Ethylene glycol}}{\underset{|\qquad\quad|}{CH_2—CH_2}\atop{OH\quad OH}}$$

2. Acetaldehyde is formed.

$$\underset{\text{2-Butene}}{CH_3—CH=CH—CH_3} \xrightarrow{O_3} CH_3—CH\overset{O}{\diagup\ \diagdown}CH—CH_3 \ (\text{with } O—O \text{ bridge}) \xrightarrow[H_2O]{Zn} \underset{\text{Acetaldehyde}}{2CH_3CHO}$$

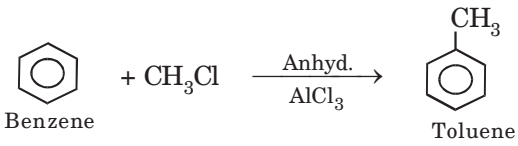
3. 2-Propanol is formed.

$$\underset{\text{Propene}}{CH_3CH=CH_2} \xrightarrow[H^+]{H_2O} \underset{\text{2-Propanol}}{CH_3-\underset{OH}{\underset{|}{CH}}-CH_3}$$

4. Ethene is formed.

$$\underset{\text{Ethyl chloride}}{CH_3CH_2Cl} + KOH\,(alc) \longrightarrow \underset{\text{Ethene}}{CH_2=CH_2} + KCl + H_2O$$

5. Toluene is formed.



6. A red precipitate of dicopper acetylide is formed.

$$\underset{\text{Ethyne}}{CH\equiv CH} + 2\,[Cu(NH_3)_2]Cl \longrightarrow \underset{\text{Red ppt.}}{CuC\equiv CCu} + 2NH_4Cl + 2NH_3$$

7. 1-Bromopropane is formed.

$$\underset{\text{Propene}}{CH_3CH=CH_2} + HBr \xrightarrow{\text{Peroxides}} \underset{\text{1-Bromopropane}}{CH_3CH_2CH_2Br}$$

The reaction proceeds according to anti-Markownikoff 's rule.

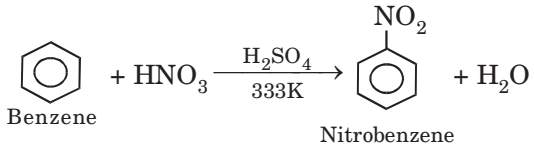
8. Acetylene is formed.

$$\underset{\text{Cal. carbide}}{CaC_2} + 2H_2O \longrightarrow \underset{\text{Acetylene}}{HC\equiv CH} + Ca(OH)_2$$

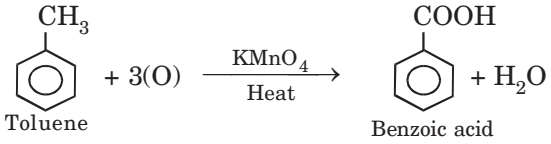
9. Ethane is formed.

$$\underset{\text{Ethyl magnesium bromide}}{C_2H_5MgBr} + H_2O \longrightarrow \underset{\text{Ethane}}{C_2H_6} + Mg\,(OH)Br$$

10. Nitrobenzene is formed.



11. Benzoic acid is formed.



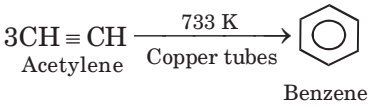
12. Methane is formed.

$$\underset{\text{Sodium acetate}}{CH_3COONa} + NaOH \xrightarrow{CaO} \underset{\text{Methane}}{CH_4} + Na_2CO_3$$

13. Ethane is formed.

$$\underset{\text{Ethyl iodide}}{CH_3CH_2I} + 2H \xrightarrow{\text{Na, alcohol}} \underset{\text{Ethane}}{CH_3CH_3} + HI$$

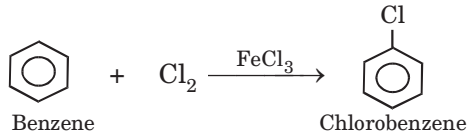
14. Benzene is formed.



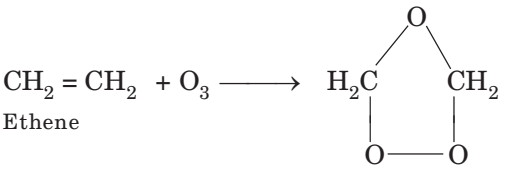
15. Ethene is formed.

$$\underset{\text{Ethylene dibromide}}{CH_2BrCH_2Br} \xrightarrow{Zn} \underset{\text{Ethene}}{CH_2 = CH_2} + ZnBr_2$$

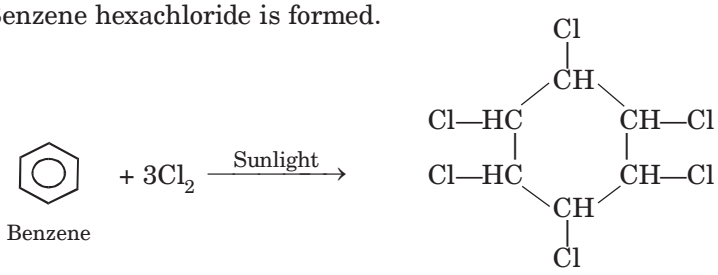
16. Chlorobenzene is formed.



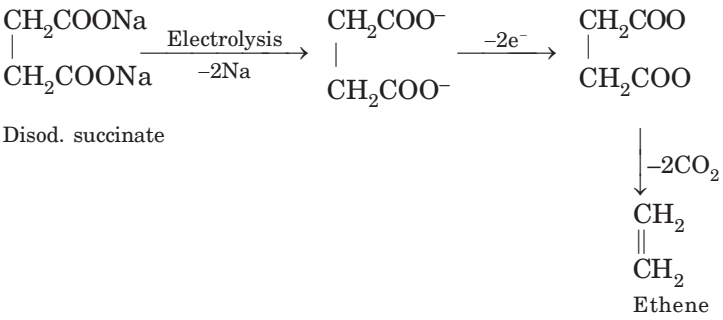
17. Ethylene ozonide is formed.



18. Benzene hexachloride is formed.



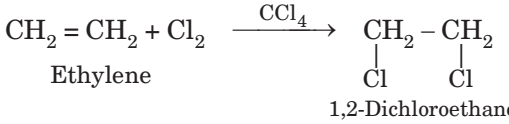
19. Ethene is obtained.



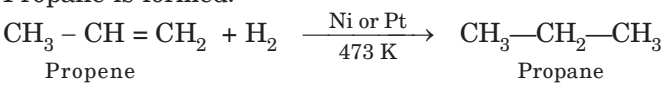
20. Formaldehyde is formed.

$$\underset{\text{Methane}}{CH_4} + O_2 \xrightarrow{MoO} \underset{\text{Formaldehyde}}{HCHO} + H_2O$$

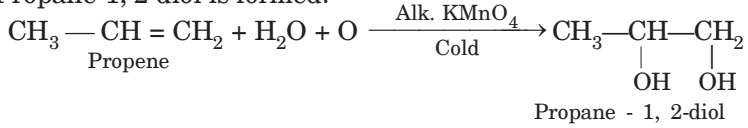
21. 1,2-Dichloroethane is formed.



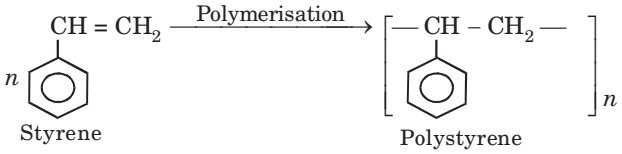
22. Propane is formed.



23. Propane-1, 2 diol is formed.



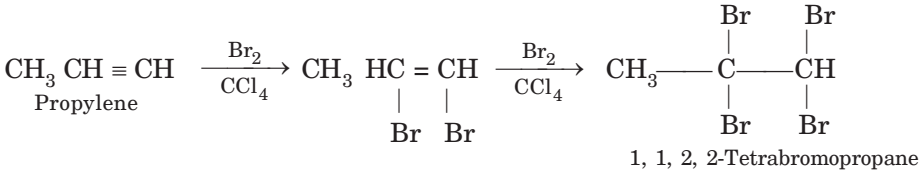
24. Polystyrene is formed.



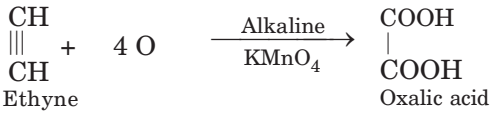
25. Carbon dioxide and water are formed.

$$\underset{\text{Ethene}}{C_2H_4} + 3O_2 \longrightarrow \underset{\text{Carbon dioxide}}{2CO_2} + \underset{\text{Water}}{2H_2O}$$

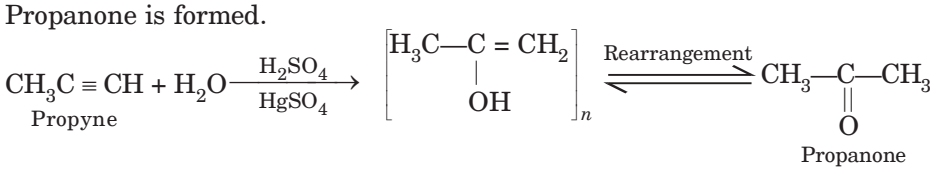
26. 1, 1, 2, 2 - Tetrabromopropane is formed.



27. Oxalic acid is formed.



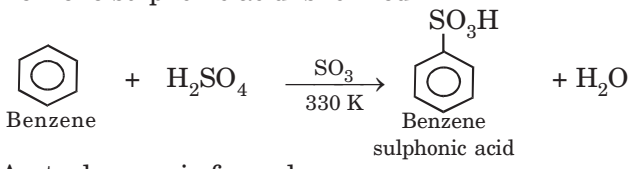
28. Propanone is formed.



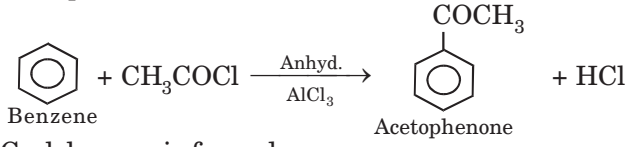
29. Disilver acetylide is formed.

$$\underset{\text{Acetylene}}{HC \equiv CH} + 2\ \underset{\substack{\text{Ammoniacal}\\ \text{silver nitrate}}}{[Ag(NH_3)_2]\ NO_3} \longrightarrow \underset{\substack{\text{Disilver}\\ \text{acetylide}}}{AgC \equiv CAg} + 2\ NH_4NO_3 + 2\ NH_3$$

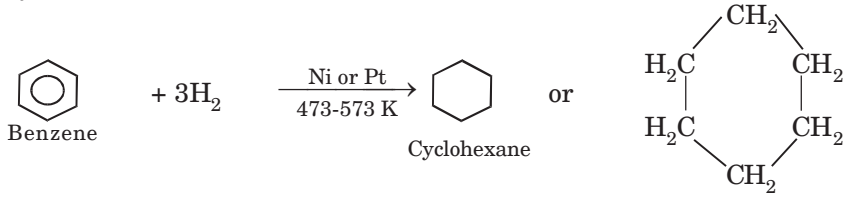
30. Benzene sulphonic acid is formed.



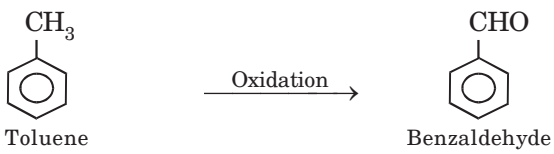
31. Acetophenone is formed.



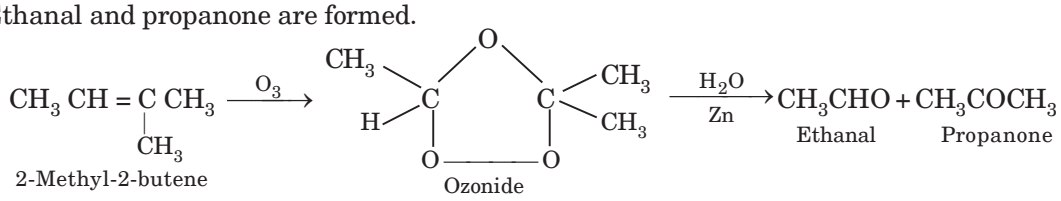
32. Cyclohexane is formed.



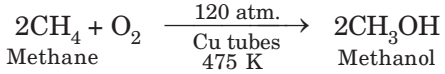
33. Benzaldehyde is formed.



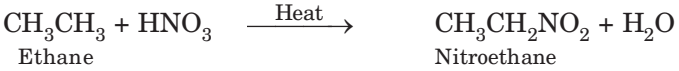
34. Ethanal and propanone are formed.



35. Methanol is formed.



36. Nitroethane is formed.



Appendix E

SOME ORGANIC COMPOUNDS POPULARLY KNOWN BY THEIR COMMON NAMES

Acetylene	$HC \equiv CH$
Acetone	$CH_3-CO-CH_3$
Acetaldehyde	CH_3CHO
Formaldehyde	$HCHO$
Neo-pentane	$C(CH_3)_4$
Vinyl chloride	$CH_2 = CHCl$
Tert-amyl alcohol	$CH_3-C(CH_3)(OH)-CH_2-CH_3$
Iso-butyl bromide	$(CH_3)_2CHCH_2Br$
Acetonitrile	CH_3CN
Allyl alcohol	$CH_2 = CH - CH_2OH$
Glycerol	$CH_2(OH)-CH(OH)-CH_2(OH)$
Allyl bromide	$CH_2 = CH - CH_2Br$
Allene	$CH_2 = C = CH_2$
Propynyl iodide	$CH \equiv CCH_2I$
Crotyl bromide	$CH_3CH = CHCH_2Br$
Acrylic acid	$CH_2 = CHCOOH$
Acrolin	$CH_2 = CHCHO$
Ethylene glycol	$CH_2(OH)-CH_2(OH)$
Propylene glycol	$CH_3CH(OH)-CH_2(OH)$
Diazomethane	CH_2N_2
Glycolic aldehyde	$HOCH_2CHO$
Glyceraldehyde	$HOCH_2CHOHCHO$
Crotonaldehyde	$CH_3CH = CHCHO$
Formic acid	$HCOOH$
Acetyl acetone	$CH_3COCH_2COCH_3$
Valeric acid	C_4H_9COOH
Malonic acid	$CH_2(COOH)_2$
Oxalic acid	$(COOH)_2$
Crotonic acid	$CH_3CH = CHCOOH$
Succinic acid	$(CH_2COOH)_2$
Maleic acid	$HC(COOH) = HC(COOH)$ (*cis*)
Fumaric acid	$HC(COOH) = HC(COOH)$ (*trans*)
Malic acid	$CH(OH)(COOH)CH_2COOH$
Tartaric acid	$CH(OH)(COOH)CH(OH)COOH$
Citric acid	$HOOCCH_2C(OH)(COOH)CH_2COOH$
Glycine	NH_2CH_2COOH
Lactic acid	$CH_3CH(OH)COOH$
Glycolic acid	$CH_2(OH)COOH$
Glyoxalic acid	$CHO-COOH$
Acetamide	CH_3CONH_2

LOGARITHMS

Log_{10}N

N	0	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529
18	2553	2577	2601	2625	2648	2672	2695	2618	2742	2765
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981
N	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

ADD NUMBERS IN MEAN DIFFERENCE COLUMNS

MEAN DIFFERENCES								
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
5	9	13	17	21	26	30	34	38
4	8	12	16	20	24	28	32	36
4	8	12	16	20	23	27	31	35
4	7	11	15	18	22	26	29	33
3	7	11	14	18	21	25	28	32
3	7	10	14	17	20	24	27	31
3	6	10	13	16	19	23	26	29
3	7	10	13	16	19	22	25	29
3	6	9	12	15	19	22	25	28
3	6	9	12	14	17	20	23	26
3	6	9	11	14	17	20	23	26
3	6	8	11	14	17	19	22	25
3	6	8	11	14	16	19	22	24
3	5	8	10	13	16	18	21	23
3	5	8	10	13	15	18	20	23
3	5	8	10	12	15	17	20	22
2	5	7	9	12	14	17	19	21
2	4	7	9	11	14	16	18	21
2	4	7	9	11	13	16	18	20
2	4	6	8	11	13	15	17	19
2	4	6	8	11	13	15	17	19
2	4	6	8	10	12	14	16	18
2	4	6	8	10	12	14	15	17
2	4	6	7	9	11	13	15	17
2	4	5	7	9	11	12	14	16
2	3	5	7	9	10	12	14	15
2	3	5	7	8	10	11	13	15
2	3	5	6	8	9	11	13	14
2	3	5	6	8	9	11	12	14
1	3	4	6	7	9	10	12	13
1	3	4	6	7	9	10	11	13
1	3	4	6	7	8	10	11	12
1	3	4	5	7	8	9	11	12
1	3	4	5	6	8	9	10	12
1	3	4	5	6	8	9	10	11
1	2	4	5	6	7	9	10	11
1	2	4	5	6	7	8	10	11
1	2	3	5	6	7	8	9	10
1	2	3	5	6	7	8	9	10
1	2	3	4	5	7	8	9	10
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1	2	3	4	4	5	6	7	8
1	2	3	4	4	5	6	7	8
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
MEAN DIFFERENCES								

Example : *Log 473.7 = 2.6749 (for 473)*
+ 6 (mean diff. for 7)
2.6755
Mantissa
Characteristic

Log 0.004516 = $\bar{3}$.6542 (for 451)
+ 6 (mean diff. for 6)
$\bar{3}$.6548

LOGARITHMS

$Log_{10}N$

ADD NUMBERS IN MEAN DIFFERENCE COLUMNS

N	0	1	2	3	4	5	6	7	8	9	MEAN DIFFERENCES 1	2	3	4	5	6	7	8	9
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7668	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	3	4
N	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
											MEAN DIFFERENCES								

Some Rules

log (a) × (b) = log a + log b $\qquad$ *log (a)^n = n log (a)*

log (a) / (b) = log a – log b $\qquad$ *ln x = 2.303 log x*

ANTI-LOGARITHMS

10^{x}

x	0	1	2	3	4	5	6	7	8	9	MEAN DIFFERENCES								
											1	2	3	4	5	6	7	8	9
.00	1000	1002	1005	1007	1009	1012	1014	1016	1019	1021	0	0	1	1	1	1	2	2	2
.01	1023	1026	1028	1030	1033	1035	1038	1040	1042	1045	0	0	1	1	1	1	2	2	2
.02	1047	1050	1052	1054	1057	1059	1062	1064	1067	1069	0	0	1	1	1	1	2	2	2
.03	1072	1074	1076	1079	1081	1084	1086	1089	1091	1094	0	0	1	1	1	1	2	2	2
.04	1096	1099	1102	1104	1107	1109	1112	1114	1117	1119	0	1	1	1	1	2	2	2	2
.05	1122	1125	1127	1130	1132	1135	1138	1140	1143	1146	0	1	1	1	1	2	2	2	2
.06	1148	1151	1153	1156	1159	1161	1164	1167	1169	1172	0	1	1	1	1	2	2	2	2
.07	1175	1178	1180	1183	1186	1189	1191	1194	1197	1199	0	1	1	1	1	2	2	2	2
.08	1202	1205	1208	1211	1213	1216	1219	1222	1225	1227	0	1	1	1	1	2	2	2	3
.09	1230	1233	1236	1239	1242	1245	1247	1250	1253	1256	0	1	1	1	1	2	2	2	3
.10	1259	1262	1265	1268	1271	1274	1276	1279	1282	1285	0	1	1	1	1	2	2	2	3
.11	1288	1291	1294	1297	1300	1303	1306	1309	1312	1315	0	1	1	1	2	2	2	2	3
.12	1318	1321	1324	1327	1330	1334	1337	1340	1343	1346	0	1	1	1	2	2	2	2	3
.13	1349	1352	1355	1358	1361	1365	1368	1371	1374	1377	0	1	1	1	2	2	2	3	3
.14	1380	1384	1387	1390	1393	1396	1400	1403	1406	1409	0	1	1	1	2	2	2	3	3
.15	1413	1416	1419	1422	1426	1429	1432	1435	1439	1442	0	1	1	1	2	2	2	3	3
.16	1445	1449	1452	1455	1459	1462	1466	1469	1472	1476	0	1	1	1	2	2	2	3	3
.17	1479	1483	1486	1489	1493	1496	1500	1503	1507	1510	0	1	1	1	2	2	2	3	3
.18	1514	1517	1521	1524	1528	1531	1535	1538	1542	1545	0	1	1	1	2	2	2	3	3
.19	1549	1552	1556	1560	1563	1567	1570	1574	1578	1581	0	1	1	1	2	2	3	3	3
.20	1585	1589	1592	1596	1600	1603	1607	1611	1614	1618	0	1	1	1	2	2	3	3	3
.21	1622	1626	1629	1633	1637	1641	1644	1648	1652	1656	0	1	1	2	2	2	3	3	3
.22	1660	1663	1667	1671	1675	1679	1683	1687	1690	1694	0	1	1	2	2	2	3	3	3
.23	1698	1702	1706	1710	1714	1718	1722	1726	1730	1734	0	1	1	2	2	2	3	3	4
.24	1738	1742	1746	1750	1754	1758	1762	1766	1770	1774	0	1	1	2	2	2	3	3	4
.25	1778	1782	1786	1791	1795	1799	1803	1807	1811	1816	0	1	1	2	2	2	3	3	4
.26	1820	1824	1828	1832	1837	1841	1845	1849	1854	1858	0	1	1	2	2	3	3	3	4
.27	1862	1866	1871	1875	1879	1884	1888	1892	1897	1901	0	1	1	2	2	3	3	3	4
.28	1905	1910	1914	1919	1923	1928	1932	1936	1941	1945	0	1	1	2	2	3	3	4	4
.29	1950	1954	1959	1963	1968	1972	1977	1982	1986	1991	0	1	1	2	2	3	3	4	4
.30	1995	2000	2004	2009	2014	2018	2023	2028	2032	2037	0	1	1	2	2	3	3	4	4
.31	2042	2046	2051	2056	2061	2065	2070	2075	2080	2084	0	1	1	2	2	3	3	4	4
.32	2089	2094	2099	2104	2109	2113	2118	2123	2128	2133	0	1	1	2	2	3	3	4	4
.33	2138	2143	2148	2153	2158	2163	2168	2173	2178	2183	0	1	1	2	2	3	3	4	4
.34	2188	2193	2198	2203	2208	2213	2218	2223	2228	2234	1	1	2	2	3	3	4	4	5
.35	2239	2244	2249	2254	2259	2265	2270	2275	2280	2286	1	1	2	2	3	3	4	4	5
.36	2291	2296	2301	2307	2312	2317	2323	2328	2333	2339	1	1	2	2	3	3	4	4	5
.37	2344	2350	2355	2360	2366	2371	2377	2382	2388	2393	1	1	2	2	3	3	4	4	5
.38	2399	2404	2410	2415	2421	2427	2432	2438	2443	2449	1	1	2	2	3	3	4	4	5
.39	2455	2460	2466	2472	2477	2483	2489	2495	2500	2506	1	1	2	2	3	3	4	5	5
.40	2512	2518	2523	2529	2535	2541	2547	2553	2559	2564	1	1	2	2	3	4	4	5	5
.41	2570	2576	2582	2588	2594	2600	2606	2612	2618	2524	1	1	2	2	3	4	4	5	5
.42	2630	2636	2642	2649	2655	2661	2667	2673	2679	2685	1	1	2	2	3	4	4	5	6
.43	2692	2698	2704	2710	2716	2723	2729	2735	2742	2748	1	1	2	3	3	4	4	5	6
.44	2754	2761	2767	2773	2780	2786	2793	2799	2805	2812	1	1	2	3	3	4	4	5	6
.45	2818	2825	2831	2838	2844	2851	2858	2864	2871	2877	1	1	2	3	3	4	5	5	6
.46	2884	2891	2897	2904	2911	2917	2924	2931	2938	2944	1	1	2	3	3	4	5	5	6
.47	2951	2958	2965	2972	2979	2985	2992	2999	3006	3013	1	1	2	3	3	4	5	5	6
.48	3020	3027	3034	3041	3048	3055	3062	3069	3076	3083	1	1	2	3	4	4	5	6	6
.49	3090	3097	3105	3112	3119	3126	3133	3141	3148	3155	1	1	2	3	4	4	5	6	6
x	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
											MEAN DIFFERENCES								

ADD NUMBERS IN MEAN DIFFERENCE COLUMNS

Example : *Antilog 1.3377 = 21.73 (for .337)*
+ 3 (mean diff. for 7)
21.76 (decimal after 2 s.f.)
↑ Indicates that the decimal point must be placed after the first 2 figures.

x	0	1	2	3	4	5	6	7	8	9
.50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228
.51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3304
.52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381
.53	3388	3396	3404	3412	3420	3428	3436	3443	3451	3459
.54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540
.55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622
.56	3631	3639	3648	3656	3664	3673	3681	3690	3698	3707
.57	3715	3724	3733	3741	3750	3758	3767	3776	3784	3793
.58	3802	3811	3819	3828	3837	3846	3855	3864	3873	3882
.59	3890	3899	3908	3917	3926	3936	3945	3954	3963	3972
.60	3981	3990	3999	4009	4018	4027	4036	4046	4055	4064
.61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159
.62	4169	4178	4188	4198	4207	4217	4227	4236	4246	4256
.63	4266	4276	4285	4295	4305	4315	4325	4335	4345	4355
.64	4365	4375	4385	4395	4406	4416	4426	4436	4446	4457
.65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560
.66	4571	4581	4592	4603	4613	4624	4634	4645	4656	4667
.67	4677	4688	4699	4710	4721	4732	4742	4753	4764	4775
.68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887
.69	4898	4909	4920	4932	4943	4955	4966	4977	4989	5000
.70	5012	5023	5035	5047	5058	5070	5082	5093	5105	5117
.71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236
.72	5248	5260	5272	5284	5297	5309	5321	5333	5346	5358
.73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483
.74	5495	5508	5521	5534	5546	5559	5572	5585	5598	5610
.75	5623	5636	5649	5662	5675	5689	5702	5715	5728	5741
.76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875
.77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012
.78	6026	6039	6053	6067	6081	6095	6109	6124	6138	6152
.79	6166	6180	6194	6209	6223	6237	6252	6266	6281	6295
.80	6310	6324	6339	6353	6368	6383	6397	6412	6427	6442
.81	6457	6471	6486	6501	6516	6531	6546	6561	6577	6592
.82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745
.83	6761	6776	6792	6808	6823	6839	6855	6871	6887	6902
.84	6918	6934	6950	6966	6982	6998	7015	7031	7047	7063
.85	7079	7096	7112	7126	7145	7161	7178	7194	7211	7228
.86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396
.87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568
.88	7586	7603	7621	7638	7656	7674	7691	7709	7727	7745
.89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925
.90	7943	7962	7980	7998	8017	8035	8054	8072	8091	8110
.91	8128	8147	8166	8185	8204	8222	8241	8260	8279	8299
.92	8318	8337	8356	8375	8395	8414	8433	8453	8472	8492
.93	8511	8531	8551	8570	8590	8610	8630	8650	8670	8690
.94	8710	8730	8750	8770	8790	8810	8831	8851	8872	8892
.95	8913	8933	8954	8974	8995	9016	9036	9057	9078	9099
.96	9120	9141	9162	9183	9204	9226	9247	9268	9290	9311
.97	9333	9354	9376	9397	9419	9441	9462	9484	9506	9528
.98	9550	9572	9594	9616	9638	9661	9683	9705	9727	9750
.99	9772	9795	9817	9840	9863	9886	9908	9931	9954	9977
x	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

ADD NUMBERS IN MEAN DIFFERENCE COLUMNS

MEAN DIFFERENCES								
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	1	2	3	4	4	5	6	7
1	2	2	3	4	5	5	6	7
1	2	2	3	4	5	5	6	7
1	2	2	3	4	5	6	6	7
1	2	2	3	4	5	6	6	7
1	2	2	3	4	5	6	7	7
1	2	3	3	4	5	6	7	8
1	2	3	3	4	5	6	7	8
1	2	3	4	4	5	6	7	8
1	2	3	4	5	5	6	7	8
1	2	3	4	5	6	6	7	8
1	2	3	4	5	6	7	8	9
1	2	3	4	5	6	7	8	9
1	2	3	4	5	6	7	8	9
1	2	3	4	5	6	7	9	10
1	2	3	4	5	7	8	9	10
1	2	3	4	6	7	8	9	10
1	2	3	5	6	7	8	9	10
1	2	4	5	6	7	8	9	11
1	2	4	5	6	7	8	10	11
1	2	4	5	6	7	9	10	11
1	3	4	5	6	8	9	10	11
1	3	4	5	6	8	9	10	12
1	3	4	5	7	8	9	10	12
1	3	4	5	7	8	9	11	12
1	3	4	5	7	8	10	11	12
1	3	4	6	7	8	10	11	13
1	3	4	6	7	9	10	11	13
1	3	4	6	7	9	10	12	13
2	3	5	6	8	9	11	12	14
2	3	5	6	8	9	11	12	14
2	3	5	6	8	9	11	13	14
2	3	5	6	8	10	11	13	15
2	3	5	7	8	10	12	13	15
2	3	5	7	8	10	12	13	15
2	3	5	7	9	10	12	14	16
2	4	5	7	9	11	12	14	16
2	4	5	7	9	11	13	14	16
2	4	6	7	9	11	13	15	17
2	4	6	8	9	11	13	15	17
2	4	6	8	10	12	14	15	17
2	4	6	8	10	12	14	16	18
2	4	6	8	10	12	14	16	18
2	4	6	8	10	12	15	17	19
2	4	6	8	11	13	15	17	19
2	4	7	9	11	13	15	17	20
2	4	7	9	11	13	16	18	20
2	5	7	9	11	14	16	18	20
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
MEAN DIFFERENCES								

Example : *Antilog 2.6459 =0.04416 (for .645)*
+ 9 (mean diff. for)
0.004425

A simple rule :

(*i*) If the characteristic is positive, then put the decimal after (n + 1) digits from the left

(*ii*) If the characteristic is negative, then put (n – 1) zeros before the first significant digit

Useful Relations

$\pi = 3.1416$	$\ln X = 2.303 \log X$	$2.303\ RT/F = 0.05916\ V$
$e = 2.71828$	$2.303\ RT = 5709\ J\ mol$ (at 25°C)	(at 25°C)

Selected Greek letters

α	alpha	ξ	xi
β	beta	ν	nu
γ	gamma	Π, π	pi
Δ, δ	delta	ρ	rho
ε	epsilon	Σ, σ	sigma
η	eta	τ	tau
θ	theta	Φ, ϕ	phi
κ	kappa	χ	chi
Λ, λ	lambda	ψ	psi
μ	mu	Ω, ω	omega

Some Useful Conversion Factors

1 kg	=	1000 gram
1 gram	=	10 decigram
	=	100 centigram
	=	1000 milligram
1 litre	=	$1\ dm^3 = 10^3\ cm^3$
1eV	=	1.6022×10^{-19} J
1 cal	=	$4.184\ J = 4.184 \times 10^7$ erg
1 J	=	10^7 erg
1 L. atm	=	24.217 cal = 101.32 J
1 Å	=	10^{-8} cm = 10^{-10} m = 0.1 nm
1 atm	=	760 nm Hg
	=	1.013×10^5 pascals
1 bar	=	10^5 pascals

Prefixes

f	p	n	m	m	c	d	k	M
femto	pico	nano	micro	milli	centi	deci	kilo	mega

USEFUL PHYSICAL CONSTANTS

Quantity	Symbol	Value
Speed of light	c	$2.9979 \times 10^8\ m\ s^{-1}$
Atomic mass unit	*amu* or *u*	1.6606×10^{-27} kg
Avogadro constant	N_A	$6.022 \times 10^{23}\ mol^{-1}$
Planck constant	h	$6.6262 \times 10^{-34}\ JK^{-1}$
Faraday constant	F	$9.64846 \times 10^4 C\ mol^{-1}$
Boltzmann constant	k	$1.3807 \times 10^{-23}\ JK^{-1}$
Charge-to-mass ratio of electron	e/m	$1.7588 \times 10^{11}\ C\ kg^{-1}$
Electronic charge	e	1.60219×10^{-19} C
Gas constant	R	$8.314\ J\ mol^{-1}\ K^{-1}$
Molar volume (STP)	V_m	$22.414 \times 10^{-3}\ m^3\ mol^{-1}$ $22.414\ dm^3\ mol^{-1}$
Mass of electron	m_e	9.10953×10^{-31} kg
Mass of proton	m_p	1.67265×10^{-27} kg
Mass of neutron	m_n	1.67495×10^{-27} kg
Rydberg constant	R	$1.096 \times 10^7\ m^{-1}$