UNIT 18

Environmental Chemistry

SYLLABUS

Environmental pollutants ; soil, water and air pollution ; chemical reactions in atmosphere, kinds of smog, major atmospheric pollutants ; acid rain, ozone and its reactions, effects of depletion of ozone layer, green house effect and global warming, indudstrial air pollution, green chemistry as an alternative tool for reducing pollution.

SECTION—I

ENVIRONMENT AND ENVIRONMENTAL POLLUTANTS

18.1. Introduction

The term "Environment" literally means "surroundings". It comprises of the following four major components :

(1) Atmosphere
(2) Hydrosphere
(3) Lithosphere and
(4) Biosphere.

Let us first try to have a brief idea of each of these segments of the environment.

(1) Atmosphere. *Atmosphere is a cover of gases that extends to a height of about 1600 km above the surface of the earth and protects the life on the earth from the harmful radiations (cosmic rays) coming from the sun or the outer space.*

Functions of the atmosphere. (*i*) It contains all those gases which are essential for the existence of life on the earth. For example, oxygen present in it is required by humans and animals for respiration and CO_2 is needed for photosynthesis in plants. Nitrogen which is present as a vital component is needed for plants indirectly as it is first converted into water soluble compounds like ammonia and then added into the soil.

(*ii*) It is an important carrier of water vapour which are needed for all forms of life.

(*iii*) Ozone present in it absorbs the harmful ultraviolet radiations coming from the sun and thus protects life on the earth.

(*iv*) It maintains heat balance of the earth by absorbing infrared radiations coming from the sun and those re-emitted from the earth. For the same reason, it controls weather and climatic conditions.

Pressure and weight of the atmosphere. The air at the surface of the earth is compressed by weight of the air above it. Hence as we go higher above the surface of the earth, the density as well as pressure of the atmosphere decrease. For each increase in altitude of about 5 km, the pressure and density of the air decrease by about one half. The total mass of the atmosphere is about 5×10^{15} tonnes. This is about one-millionth of the total mass of the earth. The atmosphere exerts a pressure of about $1 \cdot 2$ kg per square cm on our body though we do not feel it.

Temperature of the atmosphere. Different parts of the atmospehre absorb and reflect different amounts of heat of the solar radiation. Hence the temperature of the atmosphere varies from − 100°C to 1200°C (as shown in Table 18.1).

Composition of the Atmosphere or Air. The components of the atmosphere may be divided into three categories as follows :

Major components : N_2, O_2, water vapours

Minor components : Ar, CO_2

Trace components : He, Ne, Kr, Xe, CH_4, H_2, CO, N_2O, SO_2, NO, NO_2, HCHO, NH_3, O_3.

Structure or Regions of the Atmosphere. The atmosphere may be considered to be divided mainly into four regions above the surface of the earth. These regions are defined by the temperature variation with height in addition to the decrease in density and chemical composition. The names of these regions, the altitudes at which they exist, their temperature ranges and their chemical composition are given in Table 18.1. below :

TABLE 18.1. Main regions of the atmosphere

Region	Altitude from earth's surface	Temperature range	Gases/ Species present
(*i*) Troposphere	0–11 km	Decreases from 15 to −56°C	N_2, O_2, CO_2, H_2O vapour
(*ii*) Stratosphere (or ozonesphere)	11–50 km	Increases from −56 to −2°C	N_2, O_2, O_3, O-atoms
(*iii*) Mesosphere	50–85 km	Decreases from −2 to −92°C	N_2, O_2, O_2^+, NO^+
(*iv*) Thermosphere	85–500 km	Increases from −92 to 1200°C	O_2^+, O^+, NO^+, e^-

Troposphere is the most important region of the atmosphere because it is the domain of all living organisms including animals and plants. This is the region which is greatly affected by air pollution. Further, this is the region which contains water vapour which are essential for the living organisms. (Above 10 km, water is present as ice crystals). 80% of the mass of the atmosphere is in this region. The temperature of this region decreases with altitude and is minimum at about 11 km. This point is called **tropopause.** In the next region, namely **stratosphere,** the temperature begins to increase. Thus tropopause is the point of **temperature inversion.** The ozone present in the stratosphere absorbs the harmful ultraviolet radiation coming from the sun and thus acts as an umbrella for the ultraviolet radiation for the living organisms on the earth. Due to presence of ozone layer, this region is also called **ozonosphere.** The rise in temperature is due to absorption of ultraviolet rays which is converted into heat. **Mesosphere** and **thermosphere** (collectively called **Ionosphere**) contain gases in the ionized form. These ions reflect back the radiowaves to the earth. This forms the basis of wireless communication.

These regions may be represented diagrammatically as shown in Fig. 18.1.

There is one region above the thermosphere. It is called **exosphere** and is considered to the highest region of the atmosphere. It lies in the range of 500–1600 km and contains mainly atomic and ionic oxygen, hydrogen and helium. Beyond exosphere is the unbounded area called **inter-stellar space.**

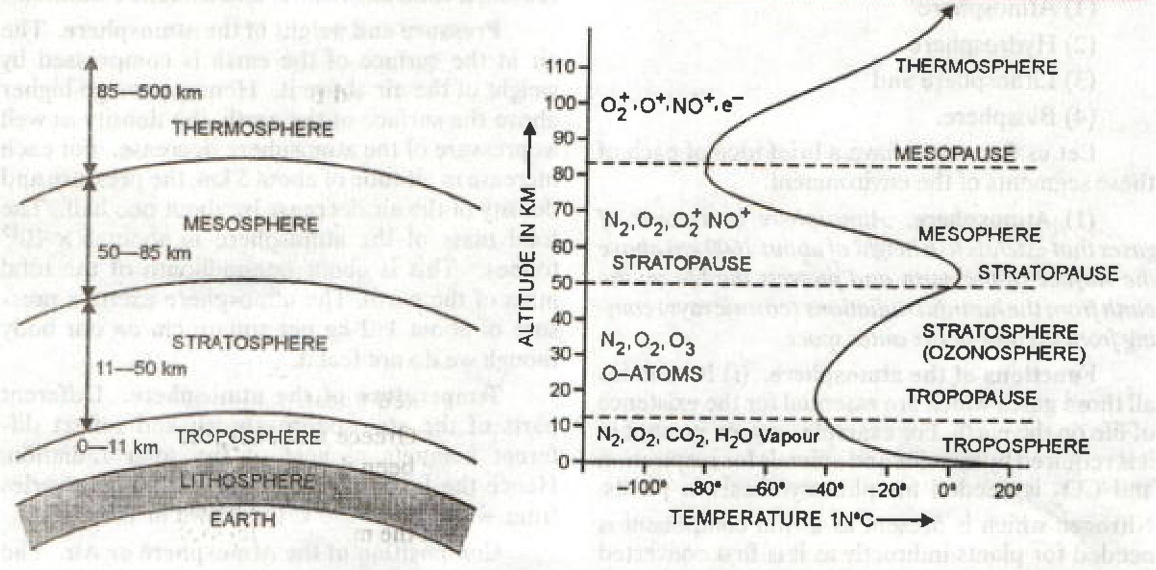

FIGURE 18.1. Regions of the atmosphere.

(2) Hydrosphere. *It forms that part of the environment which contains water in the form of sea, oceans, rivers, lakes, ponds, etc.* About 75 percent of the earth's surface is covered by hydrosphere. Most of it is in the oceans and contains about 3·5% of dissolved salt. Fresh water is present in lakes or rivers or ponds which flows into them from rain or melting of snow etc.

(3) Lithosphere. *It is the solid component of the earth consisting of soil, rocks, mountains etc.* The outermost (8 – 40 km) thick solid part of the earth is called the **crust.** The uppermost part of the earth's crust contains weathered rocks as well as organic matter and is called **soil.** This is the most important part of lithosphere because we grow plants on this part. It is also a store-house of minerals.

(4) Biosphere. *It is that part of the lithosphere, hydrosphere and atmosphere where living organisms interact with these parts and thus live together.* For example, green plants during photosynthesis give out oxygen which is added into the atmosphere, animals inhale oxygen and give out carbon dioxide which is used by plants for photosynthesis.

Lastly, it is interesting to point out that a number of "natural cyclic processes" are taking place in the environment which keep a balance of the different materials present in the environment. *A natural cyclic process is a process according to which a material of the environment is consumed in one way and then reproduced in another way.*

For example, we have water cycle, oxygen cycle, nitrogen cycle, carbon cycle, phosphorus cycle, sulphur cycle etc.

Environmental Chemistry *is that branch of science which deals with the chemical phenomena occurring in the environment.*

In fact, it is very wide branch of science which is confined not only to chemistry but also includes other branches of science like Physics, Botany, Agriculture, Life sciences, Medical sciences etc. Thus it is a **multi-disciplinary** science. A more general term for this branch is **"environmental science"** *which deals with the study of sources of pollution and the methods of monitoring and controlling the pollutants.*

18.2. Environmental Pollution and Environmental Pollutants

The addition of any undesirable material to air, water and soil by a natural source or due to human activity to such a level of concentration which adversely affects the quality of environment is called "**environmental pollution.**" *The undesirable material thus added to the environment is called a* "**pollutant.**"

There was a time when our ancestors used to talk of purity in everything that we needed for our growth. However, with the advancements in technology and industrialisation, such undesirable materials are being added into the environment that have disturbed this ecological balance (suitable co-existence of living organisms i.e. animals and plants with the non-living components lke air, water soil, etc). Today everything is polluted. The air we breathe in is polluted by the exhaust gases due to increase in vehicles, the fruit and vegetables are polluted due to use of pesticides added into the soil and water is polluted due to toxic effluents (wastes) being thrown into seas, rivers and lakes by the industries.

Environmental pollution affects human beings, animals, plants as well as materials. It does not only slow down growth of plants or bring illness to human beings but can cause havoc. A few episodes that have occurred in the recent past due to environmental pollution are given below :

(*i*) In 1952, about 4000 people died in London due to respiratory diseases (London smog).

(*ii*) During 1953-1960, hundreds of Japanese died due to eating of fish from polluted Minamata Bay.

(*iii*) The use of nuclear weapons in Hiroshima and Nagasaki killed thousands of people and the subsequent emission of radiations affected hundreds of thousands of people.

(*iv*) On December 2, 1984, Bhopal gas tragedy (due to leakage of methyl isocyanate vapours) resulted into loss of about 3000 lives and affected about 50,000 people who are still suffering from respiratory, lung, throat and eye diseases (See more details on page 18/34).

(*v*) In 1972, about 500 Iraqis died after consuming polluted wheat.

(*vi*) In Greece and Italy, the historic marble statues have been damaged by acid rain.

(*vii*) Sulphur dioxide fumes are affecting the whiteness of the marble of Taj Mahal and making it pale.

(*viii*) In the Ukaraine area of Soviet Union, thousands of people had lost their lives due to the world's worst nuclear disaster.

The main **causes of pollution** are

(*i*) Fast population growth

(*ii*) Rapid urbanisation

(*iii*) Excessive industralisation

(*iv*) Use of pesticides in Agriculture.

It is important to mention here that in a number of cases, the effect of the pollutants does not remain localized. Some of these pollutants are carried by air or by other means so rapidly that their effect can be felt within days or weaks in almost all parts of the world. For example, if a nuclear test is carried out in any part of the world, its fall out can be detected in any other part of the world within a very short period. Similarly, pesticides such as DDT have been found to have the adverse effect on animals living thousands of kilometer away from the place of their actual use.

The **pollution model** may thus be represented as follows : –

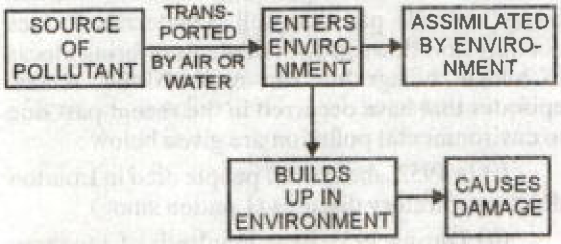

FIGURE 18.2. Origin, transport, assimilation or build up in the environment of a pollutant causing damage.

The gradual increase in pollution has now reached alarming proportions. Developed countries started taking steps to check pollution since early sixties. In 1970, they celebrated, 'Earth Day' which was organised by United Nations. In 1972, United Nations held a conference on Human Environment at Stockholm. Since then the developing countries including India have also become concious to protect their environment. The first step taken by Government of India was to set up Central Ganga Authority to take necessary steps to purify the water of Ganga and to make it pollution free. The latest step taken is the use of CNG (Condensed Natural Gas) in place of petrol and disesel in metropolitan cities.

Difference between a pollutant and a contaminant. *A contaminant is a substance which does not occur in nature but is introduced into the environment by human activity.* It may or may not be harmful to the living organism or non-living components. On the other hand, *a pollutant is a substance produced either by natural sources or by human activity or by the combined effect of both such that the concentration of that substance becomes so high in the environment that it has harmful effects on the living organisms or non-living components.* Examples of pollutants include CO, SO_2, SO_3, oxides of nitrogen, dust particles etc. One well known example of contaminant is that of pyrosulphuric acid ($H_2S_2O_7$) that had leaked from a defective tank in Delhi killing many persons and causing skin and breathing problems to many others. As pyrosulphuric acid does not occur in the atmosphere, therefore it is a contaminant. Further, as it had dangerous effects, so it is also pollutant. Generally, highly toxic substances are considered as pollutants.

Threshold Limit Value (TLV). *The permissible limit of a pollutant in the atmosphere to which if a healthy worker is exposed for 8 hours a day or 40 hours a week throughout his life, there is no adverse effect on him is called threshold limit value.* These studies are made by experimentation on animals. For example, TLV of CO is 40 ppm while that of CO_2 is 5000 ppm. On the other hand, for the poisonous gas, phosgene, TLV is only 0·1 ppm.

18.3. Types of Pollutants

Pollutants can be classified in two different ways as follows :

(1) Primary and Secondary pollutants

Primary pollutants *are those which after their formation enter the environment and remain as such.* For example, nitric oxide (NO) formed by bacterial decay or by lightning flashes (resulting into combination of N_2 and O_2 of the air) becomes a pollutant if present in excessive amount. Similarly, SO_2, NO_2 etc. are also primary pollutants.

Secondary pollutants *are those harmful materials which are formed by chemical reactions between the primary pollutants in the atmosphere or hydrosphere.* For example, hydrocarbons and oxides of nitrogen which are primary pollutants react together in the presence of sunlight to form certain compounds (*e.g.* PAN *i.e.* Peroxyacyl nitrates, see page 18/17) which are also harmful. The compounds thus formed are called secondary pollutants.

(2) **Biodegradable and Non-biodegradable pollutants**

Biodegradable pollutants are materials such as domestic sewage, cow-dung etc. which are easily decomposed by the micro-organisms either by the nature itself or by suitable treatment and thus are not harmful but if these are present in excess in the environment, they do not undergo degradation completely and thus become pollutants.

Non-biodegradable pollutants are materials such as mercury, aluminium, DDT etc. which do not undergo degradation or degrade very slowly but their presence even in very small amounts in the environment is very harmful for the humans as well as plants. They may react with other compounds present in the environment and produce even more toxic compounds.

18.4. Types of Pollution

Pollution can not only be due to addition of undesirable materials into the environments but can also be due to factors like noise, electromagnetic waves (like ultraviolet rays) etc. Further, it can be classified in two different ways as follows :

(*a*) **Depending upon the part of the environment polluted.** For example (1) Air pollution (2) Water pollution (3) Soil pollution or Land pollution.

(*b*) **Depending upon the nature of the pollutant added into the environment.**

A few common examples of this type are as follows :

(1) Radioactive pollution
(2) Plastic pollution
(3) Soap and detergent pollution
(4) Oil pollution
(5) Acid Rain pollution
(6) Smog pollution
(7) Chemical pollution
(8) Slit pollution
(9) Metal toxicity pollution
(10) Effluent pollution
(11) Noise pollution
(12) Thermal pollution

In this unit, we shall discuss briefly the pollution according to first classification.

SECTION—II

AIR POLLUTION

18.5. Introduction

Air pollution is defined as the addition of undesirable materials into the atmosphere either due to natural phenomena or due to human activity on the earth which adversely affect the quality of the air and hence affects the life on the earth.

When we talk of air pollution, we mean the pollution of air upto a height of about 80 km above the surface of the earth. This part of the air is called **homosphere** because the different constituents present in it form a homogeneous mixture.

The composition of the pure dry air is as follows :

N_2 (78·10%), O_2 (20·95%), Ar (0·93%), CO_2 (0·032%), Ne (18 ppm), He (5·2 ppm), CH_4 (1·3 ppm), Kr (1·0 ppm), H_2 (0·5 ppm), N_2O (0·25 ppm) CO (0·10 ppm), O_3 (0·02 ppm), SO_2 (0·001 ppm), NO_2 (0·001 ppm).

Air has never been pure right from the day the man started burning fuel. The oxides of carbon, nitrogen and sulphur become pollutants if their amounts exceed a certain limit (called tolerance limit).

In nature, some amount of certain pollutants is taken up by some medium present in the environment. Such a medium is called a **sink** for that pollutant. For example, oceans act as sinks for SO_2 and CO_2 and micro-organisms act as sink for CO. The living organisms like animals or plants or the materials like metals and buildings which are adversely affected by the pollutants are called **receptors or targets.**

18.6. Sources of Air Pollution

The main sources of air pollution may be classified into two categories as follows :

(1) **Natural sources.** A few example of the natural sources of pollution are as under :

(*i*) Volcanic eruptions emitting poisonous gases like CO, H_2S, SO_2 etc.

(*ii*) Forest fires and coal-refuse fires.

(*iii*) Vegetation decay.

(*iv*) Pollen grains of flowers.

(2) **Man-made sources i.e. Sources due to human activity.** A few example may be cited as follows :

(*i*) **Burning of fossil fuels** (wood, coal etc.) which produce some poisonous gases as by–products such as CO, SO_2, oxides of nitrogen (NO_x), CH_4 etc.

(*ii*) **Combustion of gasoline in the automobiles** *e.g.* cars, scooters, buses, trucks etc. They emit out poisonous gases like CO, oxides of nitrogen and unburnt hydrocarbons in addition to the particles of lead.

(*iii*) **Increase in population.** This is one of the major causes of pollution. More the population, more are the needs, greater are the unnatural methods adopted which disturb the balance or equilibrium of the atmosphere.

(*iv*) **Deforestation.** Man has been cutting trees indiscriminately to meet his needs. This has resulted in increase in the percentage of CO_2 and decrease in the percentage of oxygen in the air (because plants take up CO_2 for photosynthesis and give out O_2).

(*v*) **Fast industrialisation.** In the last few years, the number of industries in different parts of the world and their production has increased manifold. These include paper mills, sugar mills, rubber and plastic industries, metallurgical industries using smelters, leather industries, petroleum refineries, refrigeration, mining, etc. The smoke coming out of these industries contains not only carbon particles but a number of poisonous gases like CO, CO_2, SO_2, H_2S, NO, NO_2 etc. These industries are responsible for about 20% of the total air pollution.

(*vi*) **Agricultural activities.** The pesticides added to the soil or the sprays done over the crops are carried by the wind to different parts of the town where they give a foul smell and affect the health of animals and human beings.

(*vii*) **Wars.** The nuclear weapons used during wars emit out radiations which adversely affect the health and prove to be fatal.

18.7. Air Pollutants

The five major air pollutants are

(1) Carbon monoxide (CO)

(2) Hydrocarbons, (C_xH_y)

(3) Oxides of nitrogen (NO_x)

(4) Oxides of sulphur (SO_x)

(5) Particulates.

Now we shall discuss the sources, harmful effects and the methods to control each of these pollutants one by one.

(1) **Carbon monoxide (CO) as pollutant.** It is one of the most serious air pollutant. It is a colourless, odourless and tasteless gas. It is 96·5% as heavy as air.

Sources of CO production

(*a*) **Due to human activity** *e.g.*

(*i*) Incomplete combustion of fossil fuels or hydrocarbon fuels in the automobiles.

$$C + \frac{1}{2}O_2 \longrightarrow CO$$

Similarly, the complete combustion of one mole of butane (C_4H_{10}) requires 6·5 moles of oxygen. If only 6 moles of oxygen are available, one mole of CO and 3 moles of CO_2 are produced

$$C_4H_{10}\,(g) + 6\cdot5\,O_2\,(g) \longrightarrow 4\,CO_2\,(g) + 5\,H_2O\,(l)$$

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

(*ii*) Forest fires or agricultural waste burning.

(*iii*) Reaction of CO_2 (present in the air or produced due to complete combustion of carbon containing compounds) with carbon containing materials at high temperature (or with coke *e.g.* in a blast furnace)

$$CO_2 + C \longrightarrow 2\,CO$$

(*iv*) Dissociation of CO_2 at high temperatures (2000 K)

$$CO_2 \rightleftharpoons CO + O$$

At one time, it was believed that the major source of CO in the air was due to incomplete combustion of fuels. But now it has been formed that only 7% of CO arises from the man-made sources whereas the remaining 93% comes from the natural sources as given below.

(*b*) **Natural sources** e.g.

(*i*) From conversion of methane produced by the bacterial decay of living or organic matter (80%).

(*ii*) From synthesis and decay of chlorophyll (3%).

(*iii*) From oceans and other undetermined sources (10%).

Sinks of CO. Although a large amount of CO is being added into the air either due to human activity or due to natural sources, yet the level of CO in the air does not rise too much. This is because a significant amount of CO is converted into CO_2 by the micro-organisms present in the soil or by reactions in the atmosphere. In other words, microorganisms (bacteria) present in the soil act as a sink for CO.

In the urban areas where there is heavy vehicular traffic, the level of CO in the air is high as soil available is insufficient to act as a sink. On the other hand, in the rural areas, the level of CO in the air is low which is within the tolerance limit.

Harmful Effects of CO. Carbon monoxide is poisonous because it combines with haemoglobin of the red blood corpuscles (R.B.C.) about 300 times more easily than does oxygen to form carboxyhaemoglobin reversibly as follows :

$$\text{Hb} + \text{CO} \rightleftharpoons \text{HbCO}$$

The normal function of the haemoglobin is to combine with oxygen in the lungs to form oxyhaemoglobin reversibly as follows :

$$\text{Hb} + O_2 \rightleftharpoons \text{HbO}_2$$

The oxyhaemoglobin travels to the different body cells where it gives up oxygen and takes up CO_2 for return to the lungs which is then exhaled out. However if large amount of CO is present in the surrounding air, it combines more readily with the haemoglobin (as mentioned above). Thus transport of oxygen to the different parts of the body is inhibited. In other words, the body becomes oxygen-starved.

It has been found that the maximum permissible concentration of CO in the ambient air (surrounding air) is 40 ppm for an exposure of 6 – 8 hours. At concentrations greater than 100 ppm, difficulty in breathing starts and there is headache and dizziness. Concentrations of 750 ppm or more lead to acute oxygen-starvation (called **anoxia** or **asphyxiation**) and lead to coma and death.

Smokers are more prone to anoxia because they inhale a lot of CO alongwith the smoke of the cigarette. In their body, the level of carboxyhaemoglobin easily exceeds 5%. In their cases or in case of heart patients, even a level of 10 ppm of CO in the atmosphere can prove fatal.

Remedial treatment for CO poisoning :

(*i*) Carry the patient into the fresh air immediately and do not allow him to walk.

(*ii*) Loosen his clothes and take off his shoes.

(*iii*) Give artificial respiration if he is not able to breathe properly.

(*iv*) In the hospital, the patient is kept in a high pressure chamber containing oxygen at 2 to 2·5 atm pressure. Under pressure, CO of carboxyhaemoglobin is replaced by O_2 and thus transport of O_2 to different parts of the body starts.

$$\text{HbCO} + O_2 \rightleftharpoons \text{HbO}_2 + \text{CO}$$

Control of CO pollution. The main source of CO pollution due to human activity is the use of internal combustion engines in the automobiles. These engines emit a mixture of CO, NO_x, hydrocarbons and particulates. However, any method used to control any one of these pollutants results in the increase of the other pollutants. For example, if the air-fuel ratio is increased from 13 to 16, the emission of CO and hydrocarbons is reduced but the emission of NO_x increases. Thus to control the CO emission, suitable modifications have to be done in the internal combustion engine or in the quality of fuel. A few of these are as follows :

(*i*) The carburettor is adjusted so as to give a proper air-fuel ratio.

(*ii*) The exhaust system is developed in such a way that it brings about complete combustion in the fuel so that negligible CO is formed.

(*iii*) *Catalytic convertors* can be fitted into the exhaust pipe which may convert the poisonous gases like CO into harmless products before they are thrown into the air. However the use of tetraethyl lead as anti-knocking agent in the gasoline creates a problem because the catalyst like platinum get easily poisoned by the lead. That is why the use of lead-free (unleaded) gasoline has been started.

(*iv*) Modification of internal combustion engines have been done by certain companies like Honda and Tyoto of Japan instead of catalytic convertors. They contain an extra combustion chamber so that complete combustion takes place and exhaust gases have very low amounts of oxides of nitrogen and almost no carbon monoxide.

(*v*) Instead of gasoline, the use of CNG (Condensed natural gas) and LNG (Liquefied natural gas) has been started as they are pollution-free fuels.

(2) **Hydrocarbons as pollutants.** Many different hydrocarbons are present in the air. Most of these hydrocarbons are of low molecular mass (containing upto nearly 10 carbon atoms) and are gases or volatile liquids at ordinary temperatures. Methane (CH_4), the simplest hydrocarbon, is the most abundant hydrocarbon pollutant. In Los Angeles (in USA) where the vehicular traffic is very high, its amount in the air was found to be 3 ppm in 1965.

Sources of hydrocarbons :

(*a*) **Natural sources.** (*i*) Trees emit large amounts of hydrocarbons into the air.

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

$$2\,CH_2O \xrightarrow{\text{Bacteria}} CH_4 + CO_2$$

(*iii*) Domestic animals contribute a very huge amount of methane into the air every year.

(b) Man-made sources :

(*i*) Just as in case of CO, the largest man-made source of hydrocarbons pollutants is the internal combustion engine. About 15% of the total hydrocarbons present in the air is from this source. Motor fuels are mixtures of hydrocarbons. They are introduced into the air when unburnt or partially burnt fuel is emitted in the automobile exhaust. Gasoline also escapes into the air due to evaporation from the fuel tank and the engine.

(*ii*) Some hydrocarbon pollution also takes place due to burning of stationary fuel *i.e.* coal, wood, kerosene oil etc.

(*iii*) Evaporation of organic solvents like benzene, toluene etc. during industrial operations *e.g.* in paint, varnish, lacquer industries etc. add substantially (about 10%) to the total hydrocarbon pollution.

Hydrocarbon sinks. Hydrocarbons are quite stable. For example, methane has a residence time of about 3 to 7 years. However they undergo chemical reactions and photochemical reactions through a series of steps and ultimately form products like CO_2 or other water soluble products which are then washed away by rain.

Harmful effects. (*i*) At low concentrations, as they exist in the air at present, there are no harmful effects of the hydrocarbons on the human beings. However, if their concentration rises to 500-1000 ppm, they have carcinogenic effect on the lungs and cause cancer.

(*ii*) Due to their photochemical reactions with oxygen and oxides of nitrogen, they form photochemical oxidants and photochemical smog (discussed later) which have a strong damaging effect on the human being as well as plants.

Control of hydrocarbon pollution. As automobiles are the main source of hydrocarbon pollution, all those steps taken to control CO pollution are needed for controlling hydrocarbon pollution. These have already been discussed.

(3) **Oxides of nitrogen (NO_x) as pollutants.** A number of oxides of nitrogen such as NO, N_2O, NO_2, N_2O_3 and N_2O_5 (represented by the general formula NO_x) are introduced into the atmosphere due to natural sources and due to human activity. Out of these only two oxides *i.e.* NO and NO_2 are considered as pollutants. Nitric oxide (NO) is colourless and odourless gas whereas nitrogen dioxide (NO_2) is reddish brown gas having pungent smell and is suffocating in nature.

Sources of NO_x production :

(*a*) **Natural sources.** *Natural bacterial action is the only natural source which discharges NO_x, mainly in the form of NO, into the atmosphere in huge amounts. Besides, lightning discharge also results in the combination of N_2 and O_2 to form NO.*

(*b*) **Man-made sources.** (*i*) Combustion of fossil fuels (coal, oil, natural gas, gasoline etc.) both in motor vehicles and stationary sources or power plants produces so high temperatures at which oxidation of the atmospheric nitrogen takes place forming NO and NO_2 as follows :

$$N_2 + O_2 \overset{1200-1750°C}{\rightleftharpoons} 2\,NO$$

$$2\,NO + O_2 \rightleftharpoons 2\,NO_2$$

The first reaction takes place at a temperature of 1200 – 1750°C. The reverse reaction is prevented due to rapid cooling of NO. The second reaction takes place at about 1100°C.

(*ii*) Chemical industries like sulphuric acid and nitric acid industries produce NO_x as by-products which are discharged into the air.

The natural sources discharge about 5×10^3 tonnes of NO_2 into the air mainly in the form of NO whereas man-made sources release about 5×10^7

tonnes of NO_x every year all over the world. Further, the distribution of NO_x from natural sources is uniform but man-made is not uniform. Its concentration is 10 – 100 times greater in the urban areas (due to greater industrialisation and automobile population) than in the rural areas.

Sinks of NO_x pollutant. The average residence time of NO is 4 days while that of NO_2 is 3 days. During this time, they are converted into nitric acid (HNO_3) through the following reactions in which ozone plays an important role.

$$2\,NO + O_2 \longrightarrow 2\,NO_2$$

$$2\,NO_2 + 2\,H_2O + O_2 \longrightarrow 4\,HNO_3$$

$$\text{or} \quad NO_2 + O_3 \longrightarrow NO_3 + O_2$$

$$NO_2 + NO_3 \longrightarrow N_2O_5$$

$$N_2O_5 + H_2O \longrightarrow 2\,HNO_3$$

The end product is nitric acid. It comes down from the atmosphere to the surface of the earth in the form of *acid rain.* Here it reacts with the bases such as ammonia, lime etc. to form nitrates.

Harmful effects of NO_x pollution. (*i*) Neither NO nor NO_2 is a health hazard at the present pollution level. Out of the two, NO_2 is more dangerous as it is a toxic gas and affects respiratory system and damages the lungs. Its concentration at 100 ppm may be fatal for animals and human beings. Though NO has about 1500 times greater affinity than CO for haemoglobin but fortunately, it is unable to enter the blood stream from the atmosphere. But its presence in large amount may result in the increase of NO_2 by oxidation and thus become harmful.

(*ii*) Some sensitive or ornamental plants are affected by the presence of oxides of nitrogen in the ambient air (surrounding air) even at low concentrations. Their photosynthetic activity decreases and they start shedding their leaves and fruits.

(*iii*) In the presence of NO_x, textiles like cotton, rayon etc. start fading.

(*iv*) The acid rain causes the pH of the soil to decrease to 4 or 5 and thus reduces the fertility of the soil. It also has a corroding effect on marble buildings (like Taj Mahal at Agra) and the metallic structures.

(*v*) **The most serious hazard of nitrogen oxides is in the formation of an unpleasant mixture of gases and particulates that make up photochemical smog.*** It is formed as a result of photochemical reaction taking place between oxides of nitrogen and hydrocarbons forming ozone, peroxyacylnitrates (PAN) and aldehydes (RCHO). Los Angeles is famous for this type of smog.

Control of NO_x pollution. (*i*) Just as in case of CO, the catalytic convertors are used in the automobile exhaust which in the first stage convert the oxides of nitrogen to free N_2 or to a small amount of NH_3.

(*ii*) The flue gases coming from power plants or industrial units and containing NO_2 and SO_2 are freed from these gases by scrubbing them with sulphuric acid. The following reactions take place :

Ist step :

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

2nd step :

$$NO + NO_2 \longrightarrow N_2O_3$$

3rd step :

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

The flue gases thus freed from NO_2 and SO_2 are released into the atmosphere. The reaction product $NOHSO_4$ is decomposed to get H_2SO_4 which is then used again for scrubbing.

As NO_x and SO_2 are acidic oxides, scrubbing can also be done with alkaline solutions such as $Ca(OH)_2$ and $Mg(OH)_2$.

(4) Oxides of sulphur as pollutants. The two oxides of sulphur *i.e.* SO_2 and SO_3 (generally represented by the general formule SO_x) are the most serious pollutants of the atmosphere. Both are colourless gases with pungent smell.

Natural source of release of SO_2 into the atmosphere is the *volcanic eruptions.* It accounts for about 67% of the total amount of SO_2 present on the globe. The remaining 33% is discharged into the atmosphere due to human activity.

Man-made Sources mainly include the following :

(*i*) Combustion of sulphur containing coal and fuel oil in the thermal power plants.

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*The word "smog" is a combination of "smoke" and "fog". It is a misnomer here because photochemical smog is a mixture of a number of unpleasant compounds but not of smoke or fog.

(*ii*) Roasting of sulphide ores in the smelting industries. e.g. iron pyrites (FeS_2), copper byrites ($CuFeS_2$), copper glance (Cu_2S), zinc blende (ZnS), galena (PbS) etc.

e.g. $Cu_2S + O_2 \longrightarrow 2Cu + SO_2$

(*iii*) A small amount of SO_2 undergoes photolytic oxidation in the air to form SO_3

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

(*iv*) In the presence of water vapour, SO_3 reacts to form H_2SO_4 which remains suspended in the air as droplets or comes down in the form of *acid rain*.

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

As in the case of NO_x, the sulphur oxides produced from natural sources are uniformly distributed over the globe but SO_x pollution due to man-made sources is more in the industrial towns or urban areas than in non-industrial or rural areas.

Harmful effects of SO_x. (*i*) SO_2 and SO_3 are both strongly irritating to the respiratory tract. SO_2 at a concentration of 5 ppm causes throat and eye irritation (resulting into cough and tears and redness in eyes). It causes breathlessness and affects *larynx i.e.* voice box (upper part of the wind pipe). SO_3 is more harmful even at a concentration of 1 ppm and causes severe discomfort. Elderly persons and those with heart and lung diseases are most seriously affected.

(*ii*) Even a very low concentration of SO_2 (0.03 ppm) has a very damaging effect on the plants. If exposed for a long time *i.e.* a few days or weeks, it slows down the formation of chlorophyll resulting in the injury to the leaf including loss of green colour. This is called **chlorosis.**

(*iii*) Sulphur oxides as such or after being converted into H_2SO_4 damage a number of materials *e.g.*

(*a*) They damage building materials especially marble. For example, marble of Taj Mahal in Agra is being damaged due to Mathura refinery, thermal power station and a number of foundaries located nearby.

(*b*) They corrode metals, particularly iron and steel.

(*c*) They bring about fading and deterioration of fabrics, leather and paper.

(*d*) They affect the colour of the paints.

Sinks of SO_x. The sulphur oxides are converted into H_2SO_4 which combines with the limestone minerals and thus removed considerably from the atmosphere. Thus limestone minerals act as sink for sulphur oxides.

Control of SO_x pollution. The sulphur oxide pollution can be controlled in a number of ways as follows :-

(*i*) *By use of low-sulphur or sulphur – free fuels like natural gas* .

(*ii*) *By removing sulphur from the fuel (e.g. from fuel oil) before burning*.

(*iii*) *By making sulphur-free liquefied gaseous fuel from coal.*

But methods (*ii*) and (*iii*) are not economical.

(*iv*) *By using alternate sources of energy e.g.* hydroelectric power plants and nuclear plants.

(*v*) *By removal of SO_x from flue gases.* Sulphur oxides can be removed from flue gases by using chemical scrubbers. These chemical scrubbers contain a slurry of limestone. *i.e.* $CaCO_3$. The flue gases are passed through this slurry. SO_2 combines to form $CaSO_3$ whereas SO_3 combines to form $CaSO_4$ as follows :-

$$CaCO_3 + SO_2 \longrightarrow CaSO_3 + CO_2$$

$$CaCO_3 + SO_3 \longrightarrow CaSO_4 + CO_2$$

This method is economical but it produces huge amounts of solid $CaSO_3$ and $CaSO_4$, the disposal of which is a great problem.

An alternative method is based upon the reaction between HSO_3^- ions produced from SO_2 and citrate ions (H_2Cit^-). The flue gases are cooled to about 50°C and then passed through a solution containing citrate ions. The following reactions take place leading to the formation of a citrate complex

$$SO_2 + H_2O \rightleftharpoons HSO_3^- + H^+$$

$$HSO_3^- + H_2\,Cit^- \rightleftharpoons [HSO_3.\,H_2\,Cit]^{2-}$$

The above solution is then transferred into a closed vessel and H_2S gas is passed through it. As a result, sulphur precipitates out and the citrate ions are regenerated. The sulphur obtained in 99·9% pure and is thus an excellent by-product.

(5) **Particulates as pollutants.** *Small solid particles and liquid droplets suspended in air are collectively called as particulates.* Some important characteristics of these particulates are as under :

(*i*) *Size.* Their size (diameter) varies from 5 *nm* to 500,000 *nm*.

(*ii*) *Mass.* Their mass varies from 60 μg to 2000 μg per m^3 in urban and industrial areas.

(*iii*) *Concentration.* Their number varies from a few hundred per cm^3 in clear air to 10^5 per cm^3 in polluted air.

(*iv*) *Surface area.* They have large surface area due to which they have a good sorption for organic as well as inorganic matter.

(*v*) *Chemical nature.* Different types of particulates have different chemical nature.

Sources of particulates :

Natural sources include volcanic eruption, grinding, blowing of dust and soil by the wind, spraying of salts by seas and oceans etc.

Man-made sources include a large number of materials suspended in the air as particulates *e.g.*

(*i*) **Soot.** These are the smallest particulates (diameter about 5 *nm*). They are the most common particulates introduced into the air due to incomplete combustion of fossil fuels such as coal, wood fuel oil, natural gas etc.

(*ii*) **Fly ash.** These are ash particles coming alongwith the furnace flue gases and are the biggest particulates (diameter about 500,000 *nm*). They are produced due to the combustion of high-ash fossil fuels as in the thermal power plants or in smelting and mining processes.

(*iii*) **Inorganic particulates.** A few common inorganic particulates are as follows :

(*a*) **Metallic particles.** These are discharged into the air during finishing of metals.

(*b*) **Metal oxides.** They are released into the atmosphere during the combustion of fuels containing metallic compounds. For example, when coal containing iron pyrites is burnt, particulates of Fe_3O_4 are introduced into the air

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

(*c*) **Lead halides.** Tetraethyl lead, $Pb(C_2H_5)_4$, is added to gasoline to act as an anti-knocking agent. During combustion in the engine, it is oxidized to PbO which deposits in different parts of the engine and many cause damage. To avoid this damage, $Pb(C_2H_5)_4$ is mixed with dichloroethane and dibromoethane which convert PbO into $PbCl_2$ and $PbBr_2$ which are volatile and thus come alongwith the exhaust gases and introduced into the atmosphere

$$Pb(C_2H_5)_4 + O_2 + C_2H_4Cl_2 + C_2H_4Br_2 \longrightarrow CO_2 + H_2O + PbCl_2 + PbBr_2$$

Thus engine is protected but air gets polluted.

(*d*) **Asbestos dust.** Asbestos is a fibrous silicate mineral which is introduced into the atmosphere by the industries manufacturing asbestos sheets, ropes etc.

(*e*) **Sulphuric acid & nitric acid.** These particulates in the form of droplets are produced in the atmosphere when oxides of sulphur or nitrogen come in contact with the moisture.

$$2\,SO_2 + O_2 + H_2O \longrightarrow 2\,H_2SO_4$$

$$4\,NO_2 + 2\,H_2O + O_2 \longrightarrow 4\,HNO_3$$

$$\text{or } 2\,NO_2 + O_3 + H_2O \longrightarrow 2\,HNO_3 + O_2$$

Their size lies in the range of 500-1000 *nm*.

(*iv*) **Organic particulates.** Organic particulates include paraffins, olefins and aromatic compounds, particularly *polycyclic aromatic hydrocarbons* (PAH). These originate from combustion of static fuels or automobile fuels or from petroleum refineries. The polycyclic hydrocarbons are easily adsorbed on the soot particles and prove to be a great health hazard.

It may be mentioned that man-made particulates are almost equally contributed by the three sources, namely stationary fuel combustion, industrial processes and fires such as forest-fires or agricultural burning of wastes.

Alternatively, the particulates in the atmosphere may be divided into two categories *i.e.* **viable and non-viable.**

The viable particulates are the small size living organisms such as bacteria, fungi, moulds, algae etc. which are dispersed into the air. The fungi cause allergy in the human beings and diseases in the plants.

The non-viable particulates are formed as a result of the disintegration of large size materials or by condensation of small size particles or droplets. The atmosphere contains four types of non-viable particulates. These are *mist, smoke, fumes* and *dust.*

Mists are produced from the particles of the spray liquids *e.g.* from herbicides and insecticides and the condensation of the vapours in the air.

Smoke consists of small soot particles produced as a result of the combustion of organic matter *e.g.* oil, tobacco, carbon smoke etc.

Fumes are the vapours of certain materials present in the air *e.g.* metallurgical fumes (fumes of metals) and alkali fumes.

Dust denotes fine particles produced during certain industrial processes *e.g.* crushing, grinding. It consists of limestone particles, sand, pulverised coal, cement, fly ash, silica dust etc.

Harmful effects of particulate pollutants :

Effect on humans. (*i*) Small sized particulates have greater damaging effect on the humans because they can pass through the nose and enter the lungs easily whereas entry of big sized particles is checked in the nose and throat and can be easily removed from there. The small particulates thus accumulated in the lungs have large surface area and act as excellent sites for adsorption of carcinogenic compounds such as polynuclear hydrocarbons, asbestos etc. and cause diseases like lung cancer, bronchital asthma, chronic bronchitis etc. This disease of the lungs is common among the industrial workers and is called **Pneumoconiosis.**

(*ii*) Different types of lung diseases are caused by different types of particulates *e.g.* asbestos causes **asbestosis,** dust containing free silica (SiO_2) causes **silicosis,** coal miners suffer from **black lung disease** whereas textile workers suffer from **white lung disease**, beryllium compounds such as $BeCl_2$, $BeSO_4$ etc. cause **beryllosis** etc.

(*iii*) Lead particulates are highly poisonous and have a serious effect on children's brain and cause cancer.

Effect on plants. Particulates deposit on the leaves of the plants thereby blocking the stomata and retarding the transpiration of minerals from the soil. Also it hinders the intake of CO_2 from the air thereby inhibiting photosynhesis.

Effect on materials. Particulates damage a large number of materials *e.g.* soot, dust, fumes, mists etc. damage paints, clothes, draperies, buildings, soil, sculptures, monuments etc. They also accelerate corrosion of metals.

Effect on visibility. The light scattered by particulates results in poor visibility of the object in front of us as it happens at night when we are driving a car or scooter especially on foggy nights. Similarly, the sunlight scattered by particulates illuminates the air and reduces visibility due to decrease in contrast between the object and its background.

Effect on climate. Particulates act as nuclei for cloud formation and hence affect the climate. Further, they scatter and reflect back the heat of the sunlight and thus control the warming up of the earth's surface due to increase in CO_2 *i.e.* they counteract the greenhouse effect (discussed later).

Control of particulate pollution. To reduce the pollution in the air, the removal of particulates is very essential. This is done by using the following techniques which are based on settling or washing away of the particulates.

(*i*) **Gravity settling chamber.** It consists of a horizontal rectangular tank. It is so large that the effluent gases which are allowed to enter into it slow down. As a result, larger particles settle down. The fine particles, however, cannot be removed by this method.

(*ii*) **Cyclone collector.** In this technique, the gas is allowed to flow in a tight circular spiral. Due to the centrifugal force, the particulates move towards the wall and start settling down.

(*iii*) **Wet scrubbers.** In this technique, spray towers or chambers are used into which a suitable liquid (usually water) is introduced in the form of a fine spray which washes away the particulates.

(*iv*) **Electrostatic precipitator.** This is the most effective and efficient method for the removal of particulates. About 99% of the particulates can be removed by this method. It is based on the principle that particulates of all size (especially aerosol particles) can be made to acquire negative charge under the influence of high electric field. These particles are then attracted towards the positive electrode of the electric field where they start accumulating and then removed. For this purpose, the air containing the particulates is allowed to enter a tall chamber in which the electrode in the centre is subjected to a negative potential of 30,000 – 40,000 volts whereas peripheral electrode is earthed. The air inside get ionized into positive ions and electrons. The electrons are adsorbed on the particulates thereby giving them a negative charge. These are then attracted towards the positive peripheral electrode on which they accummulate and are removed by vibrating the electrode.

A schematic diagram of an electrostatic precipitator is shown in Fig. 18.3.

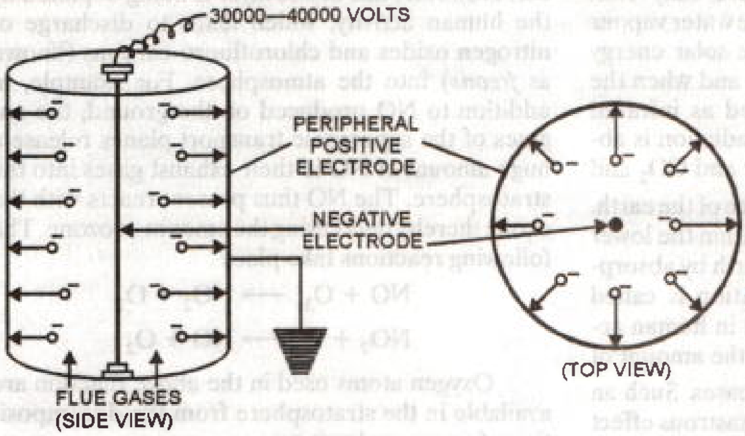

FIGURE 18.3. An electrostatic precipitator.

18.8. Industrial Air Pollution

Industries contribute maximum towards air pollution. Some of the industries and their pollutants are given below.

(1) **Sulphuric acid industry.** They release a large quantity of SO_2 and SO_3 into the atmosphere.

(2) **Nitric acid industry.** They discharge nitrogen oxides (NO_x) as pollutants into the air.

(3) **Hydrochloric acid industry.** In addition to the HCl vapours, they release toxic chlorine vapours, chlorine monoxide and unreacted hydrocarbons into the air.

(4) **Phosphoric acid industry.** In addition to the phosphoric and phosphorous acid vapours, they emit phosphorus pentoxide (P_2O_5).

(5) **Iron and steel industry.** In addition to oxides of carbon and sulphur, they introduce metal oxides as pollutants into the air.

(6) **Petrochemical refineries.** During refining operations, a number of gases are released into the atmosphere such as CO, NO_2, vapours of gasoline, kerosene, fuel oil etc. and certain organic compounds like formaldehyde.

(7) **Thermal power plants.** A large number of industries use thermal power plants. As they burn sulphur containing coal and fuel oil, they are the major source of SO_2 pollutant.

(8) **Combustion engines.** Industries making automobiles are indirectly responsible for air pollution as the internal combustion engines are responsible for the air pollution to a large extent as the exhaust gases contain a number of pollutants such as CO, NO_x, SO_x, C_xH_y, C and Pb particles etc.

In fact, a long list of industries can be prepared which are discharging pollutants into the atmosphere. These include textile industry, paper industry, sugar industry, leather industry, glass industry, alcohol manufacturing industries (breweries) etc.

18.9. Chemical Reactions Occurring in the Atmosphere

As already explained, atmosphere is divided mainly into four regions, namely, troposphere, stratosphere, mesosphere and thermosphere. All these regions of the atmosphere contain gases. In the presence of sunlight, these gases undergo chemical reactions. Thus the reactions occurring among these gases are photochemical reactions. However as the amount of these gases present in the atmosphere is very small, it makes the detection and analysis of the reaction products extremely difficult. These photochemical reactions also decide the climatic changes. Now we shall briefly describe the reactions taking place in different segments of the atmosphere one by one.

(1) **Reactions occurring in the troposphere.** This is the lowest region of the atmosphere which lies just above the surface of the earth (0 – 11 km) where all biological activity takes place. All visible events like rain, wind storms, climatic or weather changes, heat or cold take place in this region, though the life in this region is affected by the chemical reactions occurring in the other regions also. The most important reactions occurring in this region are those involving CO_2 and H_2O vapour which affect the climate as explained below :

When sunlight enters this region, CO_2 molecules present in this region absorb a large part of the energy and get excited

$$CO_2 + h\nu \longrightarrow CO_2{*} \text{ (excited molecules)}$$

These excited $CO_2{*}$ molecules then collide with the other molecules and the excess energy present in them is converted into heat. As a result, the temperature of the atmosphere may rise. Similar behaviour is also shown by the water vapour present in this region. Similarly, the solar energy reaching the earth is absorbed by it and when the earth cools, the energy is re-emitted as infrared radiation. Some of this re-emitted radiation is absorbed by tropospheric H_2O vapour and CO_2 and once again radiated back to the surface of the earth. In this way, additional heat is kept within the lower atmosphere. Such warming of the earth by absorption and re-emission of solar radiation is called **"Greenhouse effect"**. With increase in human activity, CO_2 is increasing. As a result the amount of heat radiated back to the earth increases. Such an increase in temperature may have disastrous effect on the global's climate as glaciers and polar ice caps may melt and coastal lands may get flooded. However green-house effect is being opposed by the increase in dust particles which scatter and reflect back the sunlight and the amount reaching the earth decreases.

(2) **Reactions occurring in the stratosphere.** The main reaction occurring in the stratosphere (11 – 50 km) is the formation and dissociation of ozone. The amount of ozone present in the stratosphere (10 ppm at 25 – 30 km) is much more than that present in the troposphere (0·04 ppm). The ozone is formed in the stratosphere in a two-step process. In the first step, the ultraviolet radiation coming from the sun have sufficient energy to split dioxygen (O_2) into two oxygen atoms. In the second step, these oxygen atoms react with more of dioxygen to form ozone.

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

$$O + O_2 \longrightarrow O_3$$

The ozone thus formed absorbs ultraviolet radiations and breaks down into dioxygen and an oxygen atom. Heat is given off in the reaction which warms up the stratosphere. (That is why the temperature of the stratosphere increases with temperature as already discussed).

$$O_3 \xrightarrow{h\nu} O_2 + O + \text{Heat}$$

In this way, ozone cycle is completed in the stratosphere.

The ozone layer thus present in the stratosphere is acting as protective layer for the life on the earth because it absorbs the harsh ultraviolet radiation which, if reach the earth, cause skin cancer. However, this ozone layer is being depleted by the human activity, which leads to discharge of nitrogen oxides and chlorofluoro carbons (known as *freons*) into the atmosphere. For example, in addition to NO produced on the ground, the engines of the supersonic transport planes release a huge amount of NO in their exhaust gases into the stratosphere. The NO thus present reacts with the ozone thereby decreasing the amount of ozone. The following reactions take place

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

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

Oxygen atoms used in the above reaction are available in the stratosphere from the decomposition of ozone and oxygen.

Freons are introduced into the atmosphere from aerosol sprays in which they function as propellants and from refrigerating equipment, in which they act as coolants. In the stratosphere, they first undergo photochemical decomposition, giving chlorine atoms

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

$$CFCl_3 \xrightarrow{h\nu} CFCl_2 + Cl$$

The reactive chlorine atoms then destroy the ozone through the following sequence of reactions which are repeated over the again because chlorine atoms are regenerated in the second reaction

$$Cl + O_2 \longrightarrow ClO + O_2$$

$$ClO + O \longrightarrow Cl + O_2$$

(3) **Reactions occurring in the mesosphere and thermosphere.** In these regions (collectively called as **ionosphere**), free ions and electrons are formed as a result of photochemical reactions. Some of the atom and ion forming reactions with increasing frequency with altitude are given below :

$$NO \xrightarrow{h\nu} NO^+ + e^-$$

$$O_2 \xrightarrow{h\nu} O_2^+ + e^-$$

$$N_2 \xrightarrow{h\nu} N_2^+ + e^-$$

$$N_2^+ + O \longrightarrow NO^+ + N$$

$$O \xrightarrow{h\nu} O^+ + e^-$$

$$He \xrightarrow{h\nu} He^+ + e^-$$

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

$$N_2 \xrightarrow{h\nu} N + N$$

Free ions and electrons do not stay for very long in the lower part of the mesosphere where pressure and density are quite high. They immediately collide with other ions, atoms or molecules to form neutral species. However such active species can survive for a long time in the upper atmosphere because here density and pressure are low and they do not encounter with other species with which they could combine.

18.10. Ozone Layer—Earth's Protective Umbrella

18.10.1. Formation of ozone layer. More than three billion years ago, before the evolution of life on the earth, it is believed that the atmosphere consisted mainly of CH_4, N_2, CO_2, NH_3, H_2 and H_2O vapours and there was no oxygen. When plants strated growing, they released oxygen during photosynthesis. In the stratosphere (11 – 50 km), the oxygen started partially being converted into ozone. Now at an altitude of 25 – 30 km, we have a layer in which the concentration of ozone is about 10 ppm. It is called ozone layer. This region is, therefore, also called **ozonosphere.** It does not allow the harmful ultraviolet radiations coming from the sun to reach the surface of the earth and thus protects life on the earth. That is why this ozone layer is called earth's protective umbrella.

The formation of ozone (a light bluish gas) in the stratosphere takes place in two steps. In the first step, the ultraviolet radiation coming from the sun have sufficient energy to split the dioxygen into two oxygen atoms. In the second step, the oxygen atoms react with more dioxygen to form ozone.

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

$$O + O_2 \longrightarrow O_3$$

The ozone thus formed absorbs the ultraviolet radiation and is again broken into dioxygen and an oxygen atom. Heat is given out in this reaction which warms up the stratosphere. For this reason, stratosphere is a zone of increasing temperature, as already discussed.

$$O_3 \xrightarrow{h\nu} O_2 + O + \text{Heat}$$

In this way, "ozone cycle" is completed in the stratosphere.

As the above reactions are initiated by radiation, these are called "photochemical reactions."

18.10.2. Depletion of ozone layer. Due to human activity, two types of compounds have been found to be most responsible for depleting the ozone layer and creating a hole into it. These two ozone-depleting agents are :

(*i*) **Nitric Oxide** (NO) which may be produced at the ground level due to human activity or natural sources or is produced in large amounts in the exhaust gases by the engine of supersonic transport planes and introduced directly into the stratosphere. NO reacts with ozone thereby decreasing the amount of ozone and forms NO_2 which reacts with oxygen atoms available in the stratosphere due to decomposition of ozone and oxygen (as already explained) producing back NO. Thus no NO is consumed but O_3 gets depleted

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

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

(*ii*) **Chlorofluorocarbons** (CFC) *i.e.* compounds containing chlorine, fluorine and carbon, commonly known as **freons.** These are introduced into the atmosphere from aerosol sprays in which they function as propellants and from refrigerating equipments, in which they act as coolants. They are also used as solvents and as blowing agents for plastic foams. They are chemically unreactive, non-toxic and odourless. However they have a very long life time *i.e.* they stay in the atmosphere for years and ultimately reach the upper layer where they start decomposing in the presence of UV radiation coming from the sun. For example, life time of CF_2Cl_2 *i.e.* CFC – 12 is 139 years and that of $CFCl_3$ *i.e.* CFC – 11 is 77 years.

In the stratosphere, they first undergo photochemical decomposition to give chlorine atoms or free radicals

$$CF_2Cl_2 \xrightarrow{h\nu} \cdot CF_2Cl + Cl\cdot$$

$$CFCl_3 \xrightarrow{h\nu} \cdot CFCl_2 + Cl\cdot \qquad ...(i)$$

The reactive chlorine atoms then destroy the ozone layer through the following sequence of reactions which are repeated over and again because chlorine atoms are regenerated in the second reaction

$$Cl\cdot + O_3 \longrightarrow ClO\cdot + O_2 \qquad ...(ii)$$

$$ClO^{\cdot} + O \longrightarrow Cl^{\cdot} + O_2 \qquad ...(iii)$$

It has been found that one molecule of CFC can destroy more than one thousand O_3 molecules in the stratoshere. Due to depletion of ozone (especially by CFCs), it was found in the early ninteen eighties that a large **ozone hole** has been created in the ozone layer. A similar hole was found later over the thickly populated northern hemisphere. The use of CFCs has, therefore, been completely banned.

Ozone depletion over Antarctica. Although the chain reactions, (*i*), (*ii*) and (*iii*) initiated by chlorofluorocarbons, leading to depletion of ozone take place in all parts of the stratosphere, yet the ozone hole has mainly been observed in the stratosphere over Antarctica. This is because in other parts of the stratosphere, chlorine monoxide radicals combine away with the oxides of nitrogen present in the stratosphere and the chlorine free radicals combine away with the methane present in the stratosphere as follows :

$$ClO^{\cdot} + NO_2 \longrightarrow \underset{\text{Chlorine nitrate}}{ClONO_2} \qquad ...(iv)$$

$$Cl^{\cdot} + CH_4 \longrightarrow CH_3^{\cdot} + HCl \qquad ...(v)$$

As a result, the chain reaction stops.

In Antarctica, the climatic conditions are quite different. In winters, there are special types of clouds called **Polar Stratospheric Clouds** (PSC). These clouds are of two types :

Type I clouds are those which are formed at about – 77°C and contain some solidified nitric acid trihydrate ($HNO_3 . 3 H_2O$).

Type II clouds are those which are formed at about – 85°C and contain some ice. These clouds convert chlorine nitrate formed in reaction (*iv*) and HCl formed in reaction (*v*) into HOCl and Cl_2 through the following reactions :

$$ClONO_2 + H_2O \xrightarrow{\text{Hydrolysis}} HOCl + HNO_3 \qquad ...(vi)$$

$$ClONO_2 + HCl \longrightarrow Cl_2 + HNO_3 \qquad ...(vii)$$

Hypochlorous acid (HOCl) and molecular chlorine (Cl_2) thus formed are easily converted back into reactive chlorine atoms even under mild conditions and the chain reaction starts again leading to depletion of ozone.

It is interesting to emphasize that depletion of ozone over Antarctica takes place during spring *i.e.* in the months of September and October and is replenished after spring *i.e.* in the month of November. This is because during spring, the sun shines over Antarctica and HOCl and Cl_2 formed in reactions (*vi*) and (*vii*) undergo photolysis as follows to form reactive chlorine atoms which destroy the ozone layer as already explained

$$HOCl + h\nu \longrightarrow {}^{\cdot}OH + Cl^{\cdot}$$

$$Cl_2 + h\nu \longrightarrow 2\,Cl^{\cdot}$$

Further, due to presence of PSCs, a tight whirlpool of wind is formed in the stratosphere which surrounds Antarctica. It is called **Polar Vortex.** It is so rigid that it cuts off Antarctica from the surrounding ozone rich air of the non-polar regions. As a result, the ozone hole remains unfilled. After the spring, the intensity of sunlight increases and the Vortex breaks down. The ozone rich air from surroundings immediately rushes to fill up the ozone hole.

18.10.3. Effects of depletion of ozone layer

(*i*) The most serious effect of the depletion of ozone layer or the development of ozone hole is that the ultraviolet radiation coming from the sun can pass through the stratosphere and reach the surface of the earth. This type of radiation is known to be a cancer causing agent. It has been found that with increase in the exposure to ultraviolet radiation, the chance for occurrence of skin cancer increases.

(*ii*) Exposure of eye to ultraviolet radiation damages the cornea and lens of the eye and may cause cataract or even blindness.

(*iii*) Exposure of plants to ultraviolet radiation adversely affects the plant proteins and results in the reduction of chlorophyll and harmful mutation.

(*iv*) Ozone depletion has a very strong effect on climate. Ozone layer absorbs the ultraviolet radiation and heats up the stratosphere, setting up a temperature gradient from – 56°C to – 2°C as the altitude increases from 11 to 50 km. Depletion of ozone layer will upset the heat balance of the earth.

(*v*) Ozone depletion, if not controlled, would cause ecological disturbances, which would adversely affect man and animals.

SECTION—III

SOME EFFECTS OF AIR POLLUTION

18.11. Smog and Its Kinds

The word "smog" is a combination of "smoke" and "fog". The name was so given because for the first time it was found to be formed due to condensation of some kind of fog on the carbon particles present in the smoke produced due to combustion of domestic and industrial fuels like coal and petroleum. However, now it is given a name depending upon the composition or the method of its formation or the place familiar for its formation. Depending upon these factors, it is mainly of two different types as briefly explained below :

(1) **London smog or Sulphurous smog or Classical smog.** This type of smog was first observed in London in December 1952 which killed about 4000 people. That is why it is called "London smog". Its formation is initiated by a mixture of SO_2, particulates and high humidity in the atmosphere. Many of the chemicals present in the particulates catalyse the conversion of SO_2 to SO_3 which then combines with H_2O of the humidity forming a fog of sulphuric acid droplets. These then condense on the surface of the particulates. During respiration, they are drawn into lungs causing bronchitis and respiratory problems leading to death. The reactions may be represented as follows :

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

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

It has been found that this type of smog produces much more dangerous effects than that produced by the sum total of sulphur oxides and particulates. Further, as it contains SO_2 and carbon, it is reducing in character. This type of smog is formed in the early morning hours of winter months. However, shortly after sunrise, it increases due to photochemical oxidation of SO_2 to SO_3 and subsequent combination with moisture to form sulphuric acid aerosol.

(2) **Photochemical smog or Los Angeles smog.** This type of smog was first observed in Los Angeles in 1950 and hence is named as "Los Angeles smog". It is formed when the air contains NO_2 and hydrocarbons and the mixture is exposed to sunlight. As the reaction takes place in the presence of sunlight to form the smog, it is called photochemical smog. Further, as strong sunlight is needed, this type of smog is formed in the months of summer during the day time when NO_2 and hydrocarbons are present in very large amounts due to heavy vehicular traffic. The mechanism of the formation of photochemical smog may be explained as follows :

In the presence of sunlight, NO_2 undergoes photolysis to form NO and atomic oxygen. Atomic oxygen then combines with the molecular oxygen in the presence of some molecule M (which acts as a source of transfer of energy) to form ozone, O_3. The ozone thus formed reacts with NO to regenerate NO_2 and O_2. Thus NO_2 cycle is completed. The reactions taking place may be represented as follows :

$$NO_2 \xrightarrow{h\nu} NO + O$$

$$O + O_2 \longrightarrow O_3$$

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

Thus NO and O_3 produced are used up and no extra NO_2 is added into the atmosphere. But the trouble arises if hydrocarbons are also present in the atmosphere. These hydrocarbons combine with the oxygen atom produced by the photolysis of NO_2 to form highly reactive intermediates called free radicals (which are reactive species containing unpaired electrons) which may be represented by the general formula $RCO^{\bullet}$ (dot indicates an unpaired electron). These free radicals initiate a variety of reactions, some of which may be as follows :

$$RCO^{\bullet} + O_2 \longrightarrow RCO_3^{\bullet}$$

$$RCO_3^{\bullet} + \text{Hydrocarbons} \longrightarrow RCHO, R_2C = O$$

$$RCO_3^{\bullet} + NO \longrightarrow RCO_2 + NO_2$$

$$RCO_3^{\bullet} + O_2 \longrightarrow O_3 + RCO_2$$

$$RCO_3^{\bullet} + NO_2 \longrightarrow \underset{\substack{\text{Peroxyacylnitrates}\\ \text{(PAN)}}}{RCO_3NO_2}$$

As a result, concentration of ozone, peroxyacylnitrates (PAN) and aldehydes (RCHO) and ketones (R_2CO) builds up in the atmosphere. All these compounds produce irritation in the eyes and also in the respiratory system. They also damage many materials. Ozone is particularly destructive to rubber (in which cracks are developed). It is also harmful to fabrics, crops and ornamental plants. NO_2 present gives a brown colour to the photochemical smog which reduces visibility. Airplane pilots are familiar with this type of fog hanging over the cities. As this type of smog contains O_3 and NO_2, it is oxidising in character.

The word "smog" is a misnormer here because photochemical smog contains neither smoke nor fog. It is a mixture of a number of irritation-causing compounds like NO_2, O_3, PAN, aldehydes, ketones, hydrocarbons and CO.

Control of Photochemical Smog. The formation of photochemical smog can be controlled or suppressed by adopting the following two methods :

(*i*) By fitting efficient catalytic converters in the automobiles so that the emission of nitrogen oxides and hydrocarbons by these automobiles into the atmosphere can be prevented.

(*ii*) By spraying certain compounds into the atmosphere which generate free radicals that readily combine with the free radicals that initiate the reactions forming toxic compounds of the photochemical smog.

Difference between Classical smog (London smog) and Photochemical smog (Los Angeles smog). The main points of difference are given in the table below :

Classical smog (London smog)	Photochemical smog (Los Angeles smog)
1. This type of smog was first observed in London in 1952.	**1.** This type of smog was observed in Los Angeles in 1950.
2. It is formed due to presence of SO_2 and humidity in the air which combine to form H_2SO_4 fog which deposits on the particulates.	**2.** It is formed due to photochemical reaction taking place when air contains NO_2 and hydrocarbons.
3. It involves smoke and fog.	**3.** It does not involve any smoke or fog. The word smog is a misnomer here.
4. It is formed in the months of winter particularly in the morning hours when the temperature is low.	**4.** It is formed in the months of summer during afternoon when there is bright sunlight so that photochemical reactions can take place.
5. It causes bronchitis irritation *i.e.* problem in the lungs.	**5.** It causes irritation in the eyes.
6. It is a reducing in character.	**6.** It is oxidizing in character.

18.12. Acid Rain

Acid rain is the rain water containing sulphuric acid and nitric acid (alongwith small amount of hydrochloric acid) which are formed from the oxides of sulphur and nitrogen present in the air as pollutants and has a pH of 4—5.

Formation of Acid Rain.* Due to natural sources such as bacterial action or volcanic eruptions or due to human activities mainly involving combustion of fuels like coal, wood, petroleum products etc. or from chemical industries, oxides of nitrogen (NO_x) and those of sulphur (SO_x) enter into atmosphere as pollutants. The oxides of nitrogen undergo oxidation reactions followed by reaction with the water vapours present in the atmosphere to form HNO_3 as follows :

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

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

$$NO_2 + NO_3 \longrightarrow N_2O_5$$

$$N_2O_5 + H_2O \longrightarrow 2\,HNO_3$$

The nitric acid thus formed comes down to the earth alongwith rain or reacts with the bases like NH_3 and lime to form nitrates.

The oxidation of SO_2 to SO_3 is catalysed by aerosol containing metal ions like Cu (II), Fe (II), Mn (II) and Ni (II) or by the soot particles or by the presence of NO. The SO_3 thus formed reacts with the water vapour of the air to form H_2SO_4

$$2\,SO_2 + O_2 \xrightarrow[\text{or metal ions}]{\text{NO, soot}} 2\,SO_3$$

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

HNO_3 and H_2SO_4 as formed above combine with HCl present in the air (from natural sources or man-made sources) to produce acidic precipitation which is commonly known as acid rain.

H_2SO_4 is the main contributor (60 – 70%), next is HNO_3 (30 – 40%) and least is HCl.

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*Normal rain water has a pH of about 5·6 due to dissolution of CO_2 into it ($H_2O + CO_2 \longrightarrow H_2CO_3 \rightleftharpoons 2\,H^+ + CO_3^{2-}$). When *p*H of rain water falls below 5·6, it becomes acidic.

Harmful effects of Acid Rain. (*i*) Acid rain causes extensive damage to buildings, statues and sculptual material, especially those made of marble, limestone, slate, mortar etc. The reaction with marble takes place as follows :

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

For example, Taj Mahal at Agra, which is a very popular historical monument made of marble is being attacked by acid rain due to high concentration of oxides of sulphur and nitrogen in the air over Agra because of a large number of industries in the surrounding areas which are emitting these gases. As a result, marble is being eaten up causing pitting and discolouring and making it lustreless*.

(*ii*) It also damages iron and steel structures.

(*iii*) It corrodes water pipes. As a result, heavy metals like iron, lead and copper are leached into drinking water which have toxic effects.

(*iv*) Acid rain increases the acidity of water in the lakes which is lethal for the fishes. For this reason, some of the lakes have become fishless. Thus it has greatly affected the fish population.

(*v*) Acid rain damages leaves of trees and plants and retards the growth of forests (as it happened in Swedish forests). It also retards the growth of certain crops *e.g.* peas, beans, potato, raddish, carrot, spinach etc.

18.13. Green House Effect and Global Warming

CO_2 present in normal concentration in the air is not an air pollutant. Rather it helps to maintain the temperature on the earth required for the existence of living organisms. However due to human activity such as burning of fossil fuels like coal, natural gas, petroleum etc. the amount of CO_2 in the air is increasing. This results in warming of the earth's surface and thus brings about drastic changes in the climate as explained below :

Out of sun's energy entering the atmoshere (viz about 20%) about 34% is scattered and reflected back by the particulates and the remaining 66% is absorbed by the earth. The reason for this energy reaching the earth is that visible and ultraviolet radiation (which have short, wavelengths) can pass through CO_2 and water vapour present in the atmosphere. Ultraviolet radiations are absorbed by ozone layer but visible light reaches the earth and heats it up. However, when the earth cools, the energy is re-emitted from the earth's surface in the form of infrared radiations (which have longer wavelength and have a heating effect). These radiations can be absorbed by CO_2 and H_2O vapours but cannot pass through them. The heat thus absorbed by CO_2 and H_2O vapour cannot go to the upper atmosphere and is radiated back to the surface of the earth. In this way, additional heat is kept within the lower atmosphere and warming of the earth occurs.

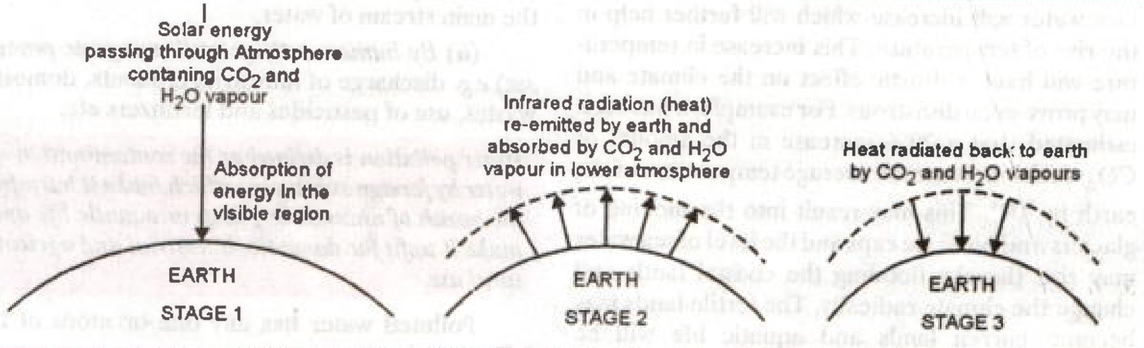

FIGURE 18.4. Stages to show production of greenhouse effect.

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*To save Taj Mahal from getting disfigured, Government of India announced an action plan in 1995. According to this plan, it was decided to clear the air in the **Taj Trapezium** *i.e.* area which included the cities of Agra, Firozabad, Mathura and Bharatpur. The action comprised of the following steps :

(*i*) All industries (about 2000) in the trapezium would be allowed to use only natural gas or LPG instead of coal or oil. A pipeline would be laid for this purpose.

(*ii*) People in these areas would also be advised to use LPG instead of coal, wood, kerosene oil etc.

(*iii*) Vehicles in the nearby area would be encouraged to use low sulphur content fuel.

This warming of the earth or global warming due to re-emission of sun's energy absorbed by the earth followed by its absorption by CO_2 molecules and H_2O vapour present near the earth's surface and then its radiation back to the earth is called "green-house effect."

The phenomenon has been named as greenhouse effect because it is similar to a green house for plants (usually needed during winter in the cold countries). A greehouse is a place where plants are grown on the soil but there are walls and roof made of glass. The sun's energy can enter through the glass but cannot go out of it. The energy is thus absorbed by the soil and the structure of the greenhouse. The energy thus absorbed is re-emitted back into the greenhouse. The same situation is observed inside a car which becomes very hot inside when it is parked in the sun for some time with its glass windows closed. In the atmosphere, CO_2 is playing the role of glass of a greenhouse. Hence it is called greenhouse effect.

Consequences of Greenhouse effect (Effect on the global climate). (*i*) If the rate at which solar radiation are arriving the earth remains constant but the amount of CO_2 in the air increases (due to human activities), the heat radiated back to the earth by CO_2 and H_2O molecules) will increase. Consequently, the temperature of the earth's surface will increase. As a result, evaporation of surface water will increase which will further help in the rise of temperature. This increase in temperature will have a drastic effect on the climate and may prove even disastrous. For example, it has been estimated that a 20% increase in the amount of CO_2 would increase the average temperature of the earth by 1°C. This may result into the melting of glaciers and polar ice caps and the level of sea water may rise thereby flooding the coastal lands and change the climate radically. The fertile lands may become barren lands and aquatic life will be seriously affected. It is estimated that the sea level may rise by about $0 \cdot 5\ m$ to $1 \cdot 5\ m$ in the next 50 to 100 years.

(*ii*) Due to higher concentration of CO_2 in the atmosphere, the plants undergoing photosynthesis will take up the gases at a faster spead. As a result, the plants in warmer climates and adequate rainfall would grow faster.

(*iii*) Higher global temperature is likely to increase the incidence of infectious diseases like malaria, dangue, yellow fever and sleeping sickness.

It is important to mention that earth is being saved from excessive heating due to certain opposing factors taking place simultaneously. For example, the increase in the amount of dust scatters away the sunlight and thus limits its amount reaching the earth.

CO_2 sinks. Two important sinks of CO_2 which help to control the amount of CO_2 in the atmosphere are

(*i*) Oceans which dissolve CO_2 into them.

(*ii*) Plants which take up CO_2 for photosynthesis.

SECTION—IV
WATER POLLUTION

18.14. Introduction

Water is one of the basic needs of household, agriculture and industry. For most of the purposes, *e.g.* drinking, washing etc. we need pure and clean water. However, the natural water (coming from rain, snow, hail etc. which is the purest form) gets contaminated or polluted in the following two ways :

(*i*) *By natural processes e.g.* washing away of the decomposed vegetable and animal wastes into the main stream of water.

(*ii*) *By human activity* (*anthropogenic processes*) *e.g.* discharge of industrial effluents, domestic wastes, use of pesticides and fertilizers etc.

Water pollution is defined as the contamination of water by foreign substances which make it harmful for health of animals or plants or aquatic life and make it unfit for domestic, industrial and agricultural use.

Polluted water has any one or more of the following signs :

(*i*) It has a bad taste to drink.

(*ii*) It has offensive odour.

(*iii*) It has unpleasant colour.

(*iv*) It has unchecked growth of weeds.

(*v*) It may have oil or grease floating on the surface.

18.15. Types of Water Pollution

Based on the sources and storages of water, water pollution may be classified into five main categories as follows :

(1) Ground water pollution. Water below the surface of the earth is called ground water. Most of the water (>90%) is present as ground water. The remaining is present in lakes, rivers, streams etc. Only about 2% is present as soil moisture above the water table which is needed for the growth of plants. Ground water collects below the surface of the earth after passing through the pores of the earthy materials which act as a filter for it and is pure. It is for this reason that well water or spring water is used for domestic purposes in rural areas. However due to disposal of domestic wastes and industrial effluents and use of fertilizers and pesticides in agriculture, a number of harmful soluble substance dissolve into the rain water and pass through the soil and enter into ground water and result in pollution, especially where the water table is high.

(2) Surface water pollution. Water present on the surface of earth in any form is called surface water. As it is an in direct contact with the atmospheric gases, a number of gases like CO_2, CO, SO_2, H_2S, NO_x etc. present in the air as pollutants dissolve into it, thereby polluting it. In addition to these atmospheric gases, the surface water also gets polluted by industrial and municipal wastes, agricultural wastes including decomposed plant and animal matter and by radioactive materials.

(3) Lake water pollution. Lakes cover a large part of the water area. The water in them gets contaminated in a number of ways as follows :

(*i*) Organic wastes from hills and toxic effluents from urban areas flow into them.

(*ii*) Industrial effluents are thrown into them.

(*iii*) Sewage treatments plants discharge toxic organic matter into them.

(*iv*) Dumping of huge amounts of sediments *i.e.* siltation of lakes.

(*v*) Inorganic nutrients from agricultural land due to surface run off.

(4) River water pollution. There are 13 major rivers in India flowing through different states. These include Ganga, Yamuna, Narmada, Brahamputra, Krishna, Cauvery, Damodar, Godavri, Hooghly, Tapti, Gomti, Sona and Chambal besides many others. There was a time when the water in these rivers was very pure and clean. Ganga jal was considered to be so pure that it could be preserved for years and a few drops of it used to be put in the mouth of relative who was on death bed. But now the water is so polluted that if taken may speed up the death of the person. Similarly, the water in the Yamuna river is so polluted that not to talk of drinking, it is unfit even for swimming or taking bath. The main reasons for the pollution of water in these rivers are :

(*i*) Industrial discharges including those from paper, textile, rayon, fertilizers, pesticides, detergents, drug industries and refineries.

(*ii*) Domestic sewage discharge.

The use of polluted water from these rivers can cause water-borne diseases like typhoid, cholera, dysentery, jaundice etc.

Government of India has, therefore, enacted laws banning the discharge of industrial or domestic waste into these rivers. Further, it has set up the following plans to clean the water of these rivers :

(*i*) Ganga Action Plan

(*ii*) Yamuna Action Plan

(*iii*) Plan to clean Hooghly water.

(5) Sea water pollution. Oceans cover about 70% of the earth's surface. They are not only a major source of water but within them lie huge stocks of food, minerals, coal, oil and gas. It is unfit for human consumption and for industrial use because it is very salty. Further, sea water is being mainly polluted by oil which poses a serious threat to the marines and fisheries.

***The pollution of sea water due to discharge of wastes from different sources into it thereby making it harmful for human health and aquatic life like fish etc. is called* marine pollution.**

Sources of oil pollution in sea water. Some of the major sources are as follows :

(*i*) Wreckage of oil tankers in open sea or accidents of ships carrying oil in the sea.

(*ii*) Discharge of oily wastes from tank washings.

(*iii*) Oil leakage from pipelines.

(*iv*) Shipping operations at the coastal belt.

(*v*) Oily wastes from oil fields or refineries located near the coast.

(*vi*) Deliberate marine pollution by crude oil, as it happened in the recent Gulf war (Iran-Iraq war in February 1990).

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 May 17, 1993 due to rupture of pipeline which damaged the ecosystem and marine life.

Other sources of pollution of sea water. A few of these are :

(*i*) Discharge of urban sewage, silt, plastics.

(*ii*) Flow of pesticides and other dumped toxic chemicals from land.

(*iii*) Discharge of radioactive wastes into sea.

(*iv*) From beach tourism discharging sanitary and kitchen wastes into sea.

Effects of oil pollution in sea water. (*i*) Oil spill causes heavy damage to fishery. Oil coating makes them unable to respire and clogs their gill slits. Aromatic compounds present in them are a poison for the fishes.

(*ii*) Emulsified oil goes deep down into the sea damaging aquatic animals and plants.

(*iii*) Oil slick results in reduction of dissolved oxygen (D.O).

(*iv*) The most affected by oil pollution are the sea-birds. Natural insulating oils and waxes which shield the birds from water are broken down by the spilled oil. As a result, due to loss of insulation, they start shivering and are frozen to death, especially in winter.

18.16. Sources of Water Pollution

The main sources responsible for the pollution of water are briefly described below :

(1) Sewage and domestic wastes *e.g.* human excreta, sewage sludge, soaps and detergents, untreated municipal sewages etc.

(2) Industrial effluents. These contain toxic chemicals and hazardous compounds including aldehydes, ketones, phenols, cyanides, oils, greases, dyes, acids, alkalies, toxic metals such as Cd, Pb, Hg etc. (cadmium and mercury can damage the kidneys whereas lead poisoning can damage kidneys, liver, brain and central nervous system). Their concentration builds up in the body as they are not excreted.

The water flowing from the acid mine contains a lot fo sulphuric acid produced by the oxidation of iron pyrites (FeS_2). The *acid-polluted water* with $pH < 3$ is fatal for the aquatic life.

(3) Agricultural discharges. These include fertilizers and pesticides, insecticides etc.

(4) Siltation. It is the process of mixing of soil or rock particles into water. It is a serious problem in hill streams. The soil particles produce turbidity in water thereby hindering the free movement of aquatic organisms and hence their growth and productivity.

(5) Thermal pollutants. These are those sources which result in the increase of temperature of the flowing water and hence adversely affect the aquatic life in them. These include thermal power plants, nuclear plants as well as industries which have cooling requirement. These units discharge their unutilized heat into the nearby flowing water. Municipal sewage disposal also causes thermal pollution because water containing sewage has a higher temperature.

(6) Radioactive discharges. They enter into water stream from different sources like nuclear reactors (nuclear power plants), nuclear tests, dumped nuclear wastes etc. The radiations emitted by them are highly hazardous.

(7) Polychlorinated biphenyls (PCBs). These compounds are used as fluids in transformers and capacitors. However, they are resistant to oxidation and their release into atmosphere causes skin disorders. They have also been found to be carcinogenic. They have been added into the list of the water pollutants only recently.

18.17. Classification of Water Pollutants

The various water pollutants may be classified into following categories :

(1) Inorganic pollutants. These include the following :

(*i*) *Acids and alkalies* from industries manufacturing acids like H_2SO_4, HNO_3, HCl, H_3PO_4 and bases like NaOH, KOH, $Ca(OH)_2$, NH_3 etc. and also as effluents from paper, textile, tanning industries. Coal mines also discharge large quantities of H_2SO_4 and $Fe(OH)_3$ produced due to reaction between iron pyrites (FeS_2), air and water.

(*ii*) *Soluble salts* like carbonates, bicarbonates, fluorides, chlorides, bromides, iodides, acetates, nitrates, sulphates, phosphates etc.

(*iii*) *Insoluble salts e.g.* calcium carbonate, calcium phosphate etc.

(*iv*) *Polyphosphates* entering into water from detergents.

(*v*) *Inorganic pesticides.* These contain metals like Cu, Cd, Fe, Mn, Zn, Co etc. and some of them contain sulphur and arsenic.

(*vi*) *Toxic metals e.g.* Pb, Hg, As, Fe, Ni, Mn, Zn and Cu which are harmful to humans, animals and plants. They are introduced into water by industrial discharges, mining processes, burning of fossil fuels and land run off etc. Industries especially responsible include paper, textile, rubber, electroplating, galvanizing, battery manufacturing etc.

(2) Organic pollutants. The different types of organic pollutants and their sources are as follows :

(*i*) *Carbohydrates and proteins e.g.* glucose, sucrose, starch, dextrin etc. from breweries, food processing industries, dairies, sugar mills, slaughter houses etc.

(*ii*) *Oils* from petroleum refineries and drilling.

(*iii*) *Aldehydes and phenols* from chemical industries.

(*iv*) *Polychlorinated Biphenyls* (PCBs) used as fluids in transformers and capacitors and also as lubricants and plasticizers.

(*v*) *Polynuclear aromatic hydrocarbons* from petroleum refineries which have carcinogenic effects on humans and animals.

(3) Sediments. These are the soil, rock or mineral particles which flow alongwith the streams before entering into water bodies. They also come from soil erosion, agriculture and construction activity. They contain organic as well as inorganic matter including trace amounts of toxic metals like As, Hg, Pb etc.

(4) Synthetic detergents. Synthetic detergents used as cleaning agent consist of a *surfactant i.e.* surface active agent which are alkyl benzene sulphonates (ABS) and a *builder* which is usually sodium phosphate or polyphosphate which is added for removing the hardness producing ions *i.e.* Ca^{2+} and Mg^{2+} ions. Besides, some *additives* are also added which consist of enzymes, perfumes and bleaching agents.

The surfactants in polluted water create a number of problems as follows :

(*i*) They do not undergo biodegradation.

(*ii*) They inhibit oxidation of organic compounds like phenol because they form an envelope around them. Hence they create problem in the treatment of waste water.

(*iii*) They stabilize the colloidal impurities which do not aggregate to settle down.

(*iv*) They produce stable foam in rivers.

The builders form soluble complexes with Ca^{2+} and Mg^{2+} ions which act as plant nutrients.

(5) Oxygen-Demanding Wastes. Dissolved oxygen is most important for all types of aquatic life.

The growth of fish is hindred if the concentration of dissolved oxygen is below 6 ppm. Oxygen enters into water through two sources :

(*i*) *Due to direct contact of the surface of water with air.* Turbulent water takes up more oxygen than still water as the bubbles get submerged.

(*ii*) *By photosynthesis of the aquatic green plants.* As it takes place in sunlight during the day time, the water gets supersaturated with oxygen. However, after sunset photosynthesis stops but the plants continue to respire and consume oxygen, therefore the amount of oxygen decreases and remains at a reasonable level.

However the discharge of human sewage and organic wastes from pulp and paper industry, tanneries and slaughter houses into water creates a problem. The microorganisms which decompose this organic waste need oxygen.

$$CH_2O\,(aq) + O_2\,(aq) \longrightarrow CO_2\,(aq) + H_2O\,(l)$$

The amount of oxygen consumed by the microorganisms in decomposing the organic waste is proportional to the amount of waste present. This is the basis of estimating organic waste present in sewage water before subjecting it to treatment.

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*In addition to the consumption of dissolved oxygen by microorganisms, it is also used up for

(*i*) bio-oxidation of the nitrogenous matter

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

(*ii*) the chemical or bio-chemical oxidation of chemical reducing agents

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

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

***The total amount of oxygen consumed by microorganisms in decomposing the waste is called* Biochemical Oxygen Demand (BOD) of the water.**

The determination of BOD of a sample of water requires 20 – 30 days for the complete decomposition of the waste which is too long a time to wait. Therefore usually we determine BOD_5 *i.e.* the amount of oxygen consumed in 5 days. The procedure is as follows :

The sample of water is saturated with oxygen and incubated for 5 days at 20°C. The remaining oxygen is measured and subtracted from the amount of oxygen originally present to get the BOD_5 and is reported in ppm which is equivalent to milligrams per litre.

Water considered pure has BOD_5 of less than 5 ppm whereas highly polluted water has BOD_5 value of more than 17 ppm. The untreated municipal sewage has BOD_5 of 100 – 400 ppm.

The measurement of BOD takes a number of days *i.e.* generally 5 days as explained above. Hence another quantity generally measured is called **Chemical Oxygen Demand (COD).** The method consists in treating the given sample of water with a known amount of an oxidizing agent, generally $K_2Cr_2O_7$ in presence of dilute H_2SO_4. All the pollutants get oxidized including those which were resistant to microbial oxidation. The amount of $K_2Cr_2O_7$ left is found by back titration against a suitable reducing agent such as Mohr salt. From the amount of $K_2Cr_2O_7$ used, the amount of oxygen consumed can be calculated from the following balanced chemical equation

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

The amount of oxygen thus consumed by the pollutants is expressed in ppm and is called COD of the given sample of water.

The decomposition of organic waste by microorganisms produces bad smell and unattractive apparance making it unfit for recreational use like swimming, boating etc. Further, decrease in the dissolved oxygen below 6 ppm, as already mentioned may result into the death of the aquatic species including fishes.

(6) Infectious agents/Disease causing agents. The municipal sewage and the municipal waste water coming from slums, hotels, restaurants, residential areas and also containing faeces and urine of infected patients, animal extcreta etc. contain disease causing microorganisms or bacteria (pathogenic microbes). The potable water gets contaminated with these microorganisms and causes diseases in humans and animals.

(7) Plant nutrients. The plant nutrients (containing N and P) flow into lakes where they support the growth of aquatic plants. These plants on decay produce unpleasant odour. Further, the microorganisms in decomposing these plants consume oxygen. As a result, the amount of dissolved oxygen in the water decreases which proves fatal for the aquatic life *i.e.* fish etc.

(8) Pesticides. These are organic compounds which are used to protect plants from pests. These are also used to stop the growth of weeds (*i.e.* unwanted plants which grow alongwith the main plant). These are mild poisons. Since weeds are not pests, the chemicals used to stop their growth are better called *herbicides.* The general term used for pesticides and herbicides is *biocide.* However the term 'pesticides' is still used quite frequently and includes herbicides. Thus pesticides include insecticides (to kill insects), fungicides (for fungi or mould), rodenticides (to kill rats and mice), herbicides (to kill weeds) etc.

These flow into lakes alongwith the rain water and cause problems to aquatic as well as human life.

(9) Radioactive pollutants. Already discussed.

(10) Thermal pollutants. Already discussed.

(11) Oil. Already discussed.

18.18. International Standards for Drinking Water

Water used for drinking must be pure as otherwise it can cause serious diseases. International standards have, therefore, been laid down for the water to be used for drinking. The chemicals that are allowed to be present and the tolerable limits upto which they are permitted and some other conditions which must be satisfied according to the international standards are given below :

	Chemical/condition	Source	Tolerable limit	Use/Harms of higher conc.
(*i*)	Fluoride	Added externally	1 ppm or 1 mg dm^{-3}	Protects teeth against decay. High conc. (> 10 ppm) are harmful to bones and teeth
(*ii*)	Lead	Lead pipes used for transport of water	50 ppb or $\mu g\ dm^{-3}$	Lead poisoning (damages kidneys, liver and brain)
(*iii*)	Other metals	—	Zn = 5 ppm Cu = 3 ppm Fe = 0·2 ppm Al = 0·2 ppm Mn = 0·05 ppm Cd = 0·005 ppm	—
(*iv*)	Sulphates	—	< 500 ppm	Higher conc. has laxative effect
(*v*)	Nitrates	—	50 ppm	Excess causes *methemoglobinemia* (blue baby syndrome) which may be linked to *stomach cancer.*
(*vi*)	pH	—	5·5—9·5	—

SECTION—V

SOIL POLLUTION

18.19. Introduction

Soil is the uppermost part of the earth's crust and is believed to have been formed as a result of decomposition and disintegration of surface rocks due to weathering over a very long period of time. It might have been formed at far off distance but is carried by strong winds and rivers to different places.

The prosperity of a nation depends upon the quality of its soil as it is the soil which provides nutrients, water and minerals for the growth of the plants. It is, in fact, the heart of biosphere.

However, large scale cutting of trees for human needs due to increase in population (*i.e.* indiscriminate deforestation), digging of minerals, increasing brick-kilns, poisonous effluents of the industries and dumping of toxic and harmful wastes, increase in the use of automobiles etc. are damaging the quality of the soil and resulting into soil pollution. In India, it is sad to point out that backwardness of our people is an additional factor for soil pollution *e.g.* using open air lavatories by slum dwellers thereby inviting pig, crows, other vultures and flies, throwing of domestic wastes including peelings of vegetables and fruits, plastics, polythene bags, etc.

18.20. Composition of the Soil

The main components of the soil are as follows :

(1) Mineral matter. It comprises of mineral particles of different sizes which originate from the rock and are formed by its disintegration. They are present as gravel, coarse sand, fine sand, slit and clay.

(2) Organic matter. This is present in the soil as a result of fallen trees and mixing of their parts such as roots, leaves etc. and also from the remains of dead animals and their excreta. These materials are decomposed by microorganisms present in the soil and convert them into **humus** (process is called *humification*). Humus has all those excellent properties which are an urgent need of the plants.

(3) Biological system. It consists of algae, bacteria, protozoa etc. which help in the decomposition of organic matter present in the soil.

(4) Soil water. The water present in the soil acts as a solvent for various organic and inorganic materials needed for the plants and also acts as a transporting agent by carrying nutrients from the soil to different parts of the plant.

(5) Soil air. It is present in the pores of the soil *i.e.* the space between the soil particles. It contains more of CO_2 and moisture than O_2. It is needed for soil microorganisms and underground parts of the plants.

The soil containing almost equal amounts of sand, slit and clay alongwith humus and 34% air and 66% water is considered to the best soil for most of the crops. It is called **loam soil.**

18.21. Sources of Soil Pollution

Some of the main sources of soil pollution are briefly described below :

(1) Industrial wastes. It has been estimated that about 50% of the raw material used by most of the industries becomes waste product which is either thrown into water or dumped into the soil nearby. This industrial waste contains huge amounts of toxic and disastrous chemicals many of which are non-biodegradable. Some of the industries responsible for soil pollution are paper and pulp mills, sugar mills, textiles, chemical industries, distilleries, metal processing industries, mining, cement and glass industries, petroleum industry etc.

(2) Urban wastes. Urban waste consists of soil refuse containing garbage and rubbish material like paper pieces, glass, plastics, used cans, leaves, polythene bags, peelings of vegetables and fruits, food wastes etc. These wastes emit out poisonous gases, toxic hydrocarbons and pathogenic microbes (bacteria) which cause diseases.

(3) Agricultural pollutants. No doubt, the use of fertilizers, pesticides, soil conditioners, fumigants etc. have increased the yield from the crops but they have polluted the soil. Their entry into food chain has adversely affected the health of the human beings and led to a number of diseases.

Some of the agricultural pollutants are briefly described below :

(i) Fertilizers. Fertilizers act as nutrients for plant but if nitrates and phosphates are present in excess, they have hazardous effects.

(ii) Pesticides. These are the chemicals that are used to kill or stop the growth of unwatned organisms. However their entry into food or drinking water adversely affects the health of human beings. These are further classified into the following different categories.

(*a*) **Insecticides.** These are the chemicals that are used to kill the insects which destroy the crop. They also help to control malaria and yellow fever. The most common insecticides in use since 1950 are the chlorinated hydrocarbons like DDT (dichlorodiphneyl trichloroethane), BHC (benzene hexachloride), aldrin etc. As they are not much soluble in water, they stay in the soil for long time and show their activity. But their disadvantage of this property is that they are absorbed by the soil and contaminate root crops like raddish, carrot etc.

(*b*) **Herbicides.** These are the compounds used to kill weeds. Earlier inorganic compounds, namely sodium chlorate ($NaClO_3$) and sodium arsenite (Na_3AsO_3) were commonly used as herbicides but arsenic compounds being toxic to mammals are no longer preferred. Instead, organic compounds such as triazines, are now considered as better herbicides especially for the corn-fields.

(*c*) **Fungicides.** These are the chemicals used to stop the growth of fungi and check plant diseases. As fungi are the plants which do not contain chlorophyll, therefore they cannot use solar energy for the synthesis of their food (carbohydrates). Hence they depend upon other plants and living organisms. As a result, the growth of the main plant is retarded. Organo-mercury compounds are the most common fungicides. However their dissociation in the soil produces mercury which is highly toxic and proves fatal if it enters into grain, as it happened in Iraq in 1972, resulting into many deaths due to consumption of wheat from fields treated with methyl mercury as fungicide.

(*iii*) **Soil conditioners.** These are used to protect the soil fertility but contain several toxic metals like Pb, As, Hg, Cd, Co etc. which may enter into the food chain.

(*iv*) **Farm wastes.** These are one of the biggest sources of soil pollution. In small towns and rural areas, there has been increase in dairies, poultries and piggery farms. Their washings collect as a *wet slurry* on the land. This may seep through the soil and pollute the ground water. If their waste (faecal matter) is dumped, it may become a breeding place for insects. Moreover, their waste may contain pathogenic bacteria and viruses which may enter the plant and then pass on to humans.

(4) Radioactive pollutants. Dumping of the nuclear wastes from the nuclear power plants into the soil has been one of the greatest source of radioactive pollution of the soil. Nuclear tests produce nuclear dust in the atmosphere which ultimately falls into the soil and pollutes it. The use of atomic and hydrogen bombs in the wars produces radioactive nuclides as the by-products. All the radioactive wastes thus produced emit radiations which are disastrous for the life on the earth.

SECTION—VI

STRATEGY FOR CONTROL OF ENVIRONMENTAL POLLUTION

18.22. Management of Waste

The two main sources for throwing waste into the environment and thus causing pollution are :

(*i*) *Household waste* which includes mainly sewage and municipal garbage.

(*ii*) *Industrial waste* which may include toxic materials.

However, if the disposal of these wastes is properly managed or they are given a suitable treatment to make them harmless, the environmental pollution can be considerably reduced. Some of the methods that are usually employed are given below :

(1) Recycling. This is the most useful method for waste disposal as a number of waste materials can be used as raw materials to manufacture the useful products again *e.g.*

(*i*) used glass bottles as well as broken pieces of glass

(*ii*) iron scrap for manufacture of steel

(*iii*) plastic wastes and polythene bags

(*iv*) used newspapers and magazines for making paper envelopes as well as for making paper.

(2) Burning and Incineration. Some combustible waste materials such as dried plant leaves etc. can be burnt to get the heat energy.

Many combustible wastes including household wastes, chemical wastes and biological wastes *e.g.* from hospitals which occupy large volume can be incinerated *i.e.* reduced to ash which can be used as a land-filling material. However the gases produced must be suitable treated before they escape into the atmosphere and cause pollution. This is one of the best methods for the disposal of polychlorinated biphenyl (PCBs) as the high temperature produced breaks the C – Cl bonds. However, the disadvantage of this method is that incomplete combustion of PCBs results in the production of highly toxic chloro compounds. Moreover, the ash produced consists of very fine particles which can enter into lungs and cause serious problems.

(3) Sewage treatment. The sewage is treated in a number of steps as follows :

(*i*) Large size materials are filtered through screens. They are then used to fill low lying land.

(*ii*) It is allowed to stand in tanks. As a result, many solids settle down (called *sludge*) while oils and grease float on the surface from where they can be skinned off.

(*iii*) The organic materials present in it are allowed to undergo microbial oxidation.

(*iv*) Finally, the waste water is suitably treated for the removal of phosphate followed by coagulation, filteration and disinfecting it by adding chlorine.

(4) Digesting. This method is used to degrade a number of toxic organic wastes. The method consists in degrading the waste by microorganisms in the absence of oxygen (called *anaerobic digestion*). The main products formed are CO_2 and CH_4.

$$2\,[CH_2O] \longrightarrow CO_2\,(g) + CH_4\,(g)$$

Methane can be used as a fuel.

(5) Dumping. Dumping of the sewage sludge into sea has been very common in all the countries. However, now a days dumping of the sludge into land is preferred. This is because it contains compounds of nitrogen and phosphorus which act as a good fertilizer for the soil. However, damping of urban sewage has to be controlled carefully because it contains many toxic metals.

18.23. Green Chemistry as an Alternative Tool for Reducing Pollution

We have discussed in this unit the hazards of environmental pollution. One of the major causes of this pollution is the rapid industrialization particularly the development of those industries which either produce or use toxic chemicals. One way to protect our environment from chemical effluents and wastes is to use **Green chemistry.**

By green chemistry, we mean producing the chemicals of our daily needs using such reactions and chemical processes which neither use toxic chemicals nor emit such chemicals into the atmosphere.

Although it is a challenging task but some initial efforts have already been made to achieve this goal.

Green chemistry does not employ toxic reagents or solvents and severe conditions but use mild and environmental friendly reagents, such as sunlight, microwaves, sound waves and enzymes. Each of these is briefly described below :

(*i*) **Use of sunlight and microwaves.** The use of sunlight and ultraviolet light have given birth to **photochemistry.** During the past forty years, a number of photochemical reactions have been studied and their conditions standardized. One major advantage of these reactions is that sometimes the products of photochemical reactions are such that they cannot be obtained by usual chemical methods. Recently, many known reactions have also been carried out using microwave ovens. In these reactions, no toxic solvents are used but only the reactants in proper ratios are mixed on a solid support such a alumina and exposed to microwaves. The reaction is complete within minutes and yields are not only comparable but in some cases, they are even higher than those obtained under severe conditions using toxic solvents. Thus the use of microwaves have not only reduced the time of the reaction but have also increased the yields. Efforts are, however, needed to develop the solid supports and optimise the dose of microwave radiations to realize the desired results.

(*ii*) **Use of sound waves.** Instead of microwaves, sound waves have also been used to carry out certain known chemical reactions with encouraging results. *This branch of chemistry is called* **sonochemistry.** Here again efforts are needed to develop conditions to achieve the desired goals.

(*iii*) **Use of enzymes.** One of the most thoroughly investigated environmental friendly reagents are enzymes. These work in aqueous solutions and at ambient temperatures. Using these enzymes many biochemical methods have been developed to prepare precursors and intermediates of certain medicines and antibiotics. For example, semi-synthetic penicillins such as *amphicillin* and *amoxycillin*, have been prepared using this technique.

It is interesting to point out that usually addition reaction are preferred so that the starting materials completely enter into final products and there is no undesirable material produced which may have to be disposed of or treated. Further, now complete data is available about the list of hazardous and toxic chemicals so that the task of chemists has been simplified.

A few achievements of green chemistry in recent years are outlined below :

(*i*) **Synthesis of ibuprofen.** A new method has been developed which not only gives 99% yield but uses smaller quantities of solvents and does not give any waste products.

(*ii*) **Catalytic dehydrogenation of diethanolamine.** To carry out this reaction, used for the production of herbicide, a new technique has been developed in which the reactants as well as the product are environment-friendly unlike the old classical reactions in which cyanide and formaldehyde were used.

(*iii*) **Replacement of chlorofluorocarbons (CFCs) by CO_2 as blowing agent.** In the manufacture of polystyrene foam sheets, earlier chlorofluorocarbons were used as blowing agents. These chemicals resulted in ozone depletion, global warming and formation of smog. New methods have been developed in which CFCs have been replaced by CO_2.

(*iv*) **Replacement of organotins by 'Sea-nine' as antifouling compound in sea marines.** Earlier organotins were used as antifouling agents in sea marines. However as they are stable compounds, they persist in the marine for long time and thus cause pollution. These have now been replaced by the newly designed safer compound called 'Sea-nine'.

From the above discussion, it is evident that if concerted efforts are made to develop green chemical products, it will certainly help us to keep our environment pollution free.

Conceptual Questions

Q. 1. Why does rain water normally have a *p*H of about 5·6 ? When does it become acid rain ? (*N.C.E.R.T.*)

Ans. Normally rain has a *p*H of about 5·6 due to dissolution of CO_2 of the atmosphere into it ($CO_2 + H_2O \longrightarrow H_2CO_3 \rightleftharpoons 2H^+ + CO_3^{2-}$). When the *p*H of rain falls below 5·6, it becomes acid rain.

Q. 2. Why is acid rain considered as a threat to Taj Mahal ? (*N.C.E.R.T.*)

Ans. Taj Mahal is made of marble. The acid rain contains H_2SO_4 which attacks the marble ($CaCO_3$) thereby pitting it, discolouring it and making it lustreless

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

Q. 3. Explain giving reasons "The presence of CO reduces the amount of haemoglobin available in the blood for carrying oxygen to the body cells." (*N.C.E.R.T.*)

Ans. CO combines with haemoglobin of the red blood corpuscles (RBCs) about 300 times more easily than oxygen to form carboxyhaemoglobin reversibly as follows :

$$Hb + CO \rightleftharpoons HbCO.$$

Thus it is not able to combine with oxygen to form oxyhaemoglobin and transport of oxygen to different body cells cannot take place.

Q. 4. State briefly the reactions causing ozone layer depletion in the stratosphere. (*N.C.E.R.T.*)

Ans. Refer to page 18/15 under Sec. 18.10.2.

Q. 5. Fish do not grow as well in warm water as in cold water. Why ? (*N.C.E.R.T.*)

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

Q. 6. **"Oxygen plays a key role in the troposphere while ozone in the stratosphere". Elucidate.** (*N.C.E.R.T.*)

Ans. All biological activity takes place in the troposphere for which oxygen is required. Ozone in the stratosphere absorbs the harsh ultraviolet radiation coming form the sun which otherwise cause skin cancer, affect the cornea of the eye and may cause even blindness.

Very Short Answer Questions CARRYING 1 MARK

Q. 1. What is the approximate total mass of the atmosphere ?

Ans. 5×10^{15} tonnes.

Q. 2. What is the temperature range of the atmosphere ?

Ans. —110°C to 1200°C.

Q. 3. Name the different regions of the atmosphere alongwith their altitudes and temperature ranges.

Ans. Troposphere (0—11 km, 15 to —56°C), stratosphere (11—50 km, —56 to —2°C), mesosphere (50—85 km, —2 to —92°C), thermosphere (85—500 km, —92 to 1200°C).

Q. 4. In what regions of the atmosphere, the temperature increases with attitude and in which regions it decreases.

Ans. Temperature increases with altitude in stratosphere and thermosphere while it decreases in troposphere and mesosphere.

Q. 5. What do you mean by "inversion temperature" in different regions of the atmosphere ?

Ans. When we go from one region of the atmosphere to the next adjoining region, the trend of temperature changes from increae to decrease or vice versa. This is called inversion temperature.

Q. 6. What gas leaked to bring havoc in Bhopal tragedy ?

Ans. Methyl isocyanate (MIC).

Q. 7. What are primary and secondary pollutants of the air ?

Ans. Primary pollutants are those which after their formation remain as such *e.g.* NO. Secondary pollutants are those which are formed as a result of reaction between primary pollutants *e.g.* PAN (peroxyacylnitrates).

Q. 8. What is the %age of CO_2 in the pure dry air ?

Ans. About 0·032%.

Q. 9. Name three natural sources of air pollution.

Ans. Volcanic eruptions, forest fires and pollen grains of flowers.

Q. 10. Name three gases which are major air pollutants.

Ans. CO, NO_x and SO_x.

Q. 11. What is the most important sink of CO pollutant ?

Ans. Soil microorganism.

Q. 12. What is the compound formed when CO combines with blood ?

Ans. Carboxyhaemoglobin (HbCO).

Q. 13. What is anoxia or asphyxiation ?

Ans. Acute oxygen starvation in the body (due to CO poisoning) is called anoxia or asphyxiation.

Q. 14. How are NO and NO_2 formed in the atmosphere ?

Ans. NO is formed due to reaction between N_2 and O_2 during lightning or combustion of fossil fuels. It is further oxidized to NO_2.

Q. 15. How are flue gases from industries freed from oxides of nitrogen and sulphur ?

Ans. By scrubbing them with conc. H_2SO_4 or with alkaline solutions like $Ca(OH)_2$ and $Mg(OH)_2$.

Q. 16. What is chlorosis ?

Ans. Slowing down the formation of chlorophyll in plants due to presence of SO_2 as pollutant is called *chlorosis.*

Q. 17. What are the reactions involved in removing SO_2 from the atmosphere by passing it through a solution containing citrate ions ?

Ans. $SO_2 + H_2O \rightleftharpoons HSO_3^- + H^+$, $HSO_3^- + H_2Cit^- \longrightarrow \underset{\text{(Complex)}}{(HSO_3 \cdot H_2Cit)^{2-}}$

Q. 18. What is the size range of particulates ?

Ans. 5 *nm* to 500,000 *nm*.

Q. 19. What is the role of dichloroethane and dibromoethane when added to gasoline alongwith tetraethyl lead ?

Ans. They convert PbO produced into volatile $PbCl_2$ and $PbBr_2$.

Q. 20. What type of aromatic compounds are present as particulates in the air ?

Ans. Polycyclic aromatic hydrocarbons (PAH).

Q. 21. What are 'asbestosis' and 'silicosis' ?

Ans. The lung disease caused by particulates of asbestos is called 'asbestosis' and that caused by those of silica is called 'silicosis'.

Q. 22. Who are the people who usually suffer from 'black lung disease' and who are those who suffer from 'white lung disease' ?

Ans. Coal miners suffer from black lung disease and textile workers suffer from white lung disease.

Q. 23. How particulates help in the cloud formation ?

Ans. They act as nuclei for cloud formation.

Q. 24. Which zone is called ozonosphere ?

Ans. Stratosphere.

Q. 25. Which main compounds are causing damage to ozone layer ?

Ans. NO and freons.

Q. 26. What gaseous species are present in the mesosphere and thermosphere ?

Ans. Gaseous ions like NO^+, O_2^+, N_2^+, O^+ and atoms of N and O.

Q. 27. Which disease is caused due to hole in the ozone layer and why ?

Ans. Ultraviolet rays will reach the earth after passing through the hole and cause skin cancer.

Q. 28. What is the composition of 'London smog' ?

Ans. Fog of H_2SO_4 droplets deposited on the particulates.

Q. 29. In which season and what time of the day, there is 'London smog' ?

Ans. In winter during the morning hours.

Q. 30. What is the nature of 'London smog' ?

Ans. Reducing.

Q. 31. What is the composition of 'photochemical smog' ?

Ans. It is a mixture of a number of irritation causing compounds like NO_2, O_3, peroxyacylnitrates (PAN), aldehydes, ketones, hydrocarbons and CO.

Q. 32. Why 'photochemical smog' is so called ?

Ans. It is because it is formed as a result of photochemical reaction (*i.e.* in presence of sunlight) between oxides of nitrogen and hydrocarbons.

Q. 33. In which season and what time of the day, there is photochemical smog ?

Ans. In summer, in the afternoon.

Q. 34. What is the nature of 'photochemical smog' ?

Ans. It is oxidizing in nature.

Q. 35. Which acids are present in the acid rain ?

Ans. H_2SO_4, HNO_3 and HCl.

Q. 36. What is the role of CO_2 in the 'greenhouse effect' ?

Ans. Heat from the sun after being absorbed by the earth is remitted by the earth and absorbed by CO_2 and then radiated back to the earth, thereby warming it.

Q. 37. Name two important sinks of CO_2.

Ans. Oceans (which dissolve it) and plants (which use it for photosynthesis).

Q. 38. What is marine pollution ?

Ans. Pollution of sea water due to discharge of wastes into it is called marine pollution.

Q. 39. What type of pollution affects the sea-birds ?

Ans. Oil pollution.

Q. 40. What is siltation ?

Ans. Mixing of soil or rock particles into water is called siltation.

Q. 41. What are the main sources of thermal pollution ?

Ans. Thermal power plants and nuclear plants.

Q. 42. What are surfactants chemically used in synthetic detergents ?

Ans. Alkyl benzene sulphonates.

Q. 43. What is the role of builder in synthetic detergents ?

Ans. It removes hardness producing ions viz. Ca^{2+} and Mg^{2+} ions.

Q. 44. What is BOD ?

Ans. The amount of oxygen consumed by microorganisms in decomposing waste in a sample of sewage water is called BOD (Biochemical Oxygen Demand).

Q. 45. What is COD ? Which chemical substance is generally used in its measurement ?

Ans. COD stands for Chemical Oxygen Demand. It is measured by treating the given sample of water with an oxidizing agent, generally $K_2Cr_2O_7$ in presence of dilute H_2SO_4.

Q. 46. Why COD is preferred over BOD ?

Ans. COD can be found in a few minutes whereas BOD requires at last 5 days.

Q. 47. What is humification ?

Ans. The decomposition of organic material (leaves, roots etc.) in the soil by microorganism to produce humus is called humification.

Q. 48. What is loam soil ?

Ans. The soil containing 34% air, 66% water alongwith humus is called loam soil. It is best for the crops.

Q. 49. What are viable and non-viable particulates ?

Ans. Viable particulates are small size living organisms such as bacteria, fungi, moulds, algae etc. Non-viable particulates are formed by disintegration of large size materials or condensation of small size particles or droplets *e.g.* mist, smoke, fume and dust.

Q. 50. Why there is ozone depletion mainly over Antarctica ?

Ans. This is because in other parts of the stratosphere, chlorine free radicals combine away but in Antarctica, the compounds formed are converted back into chlorine free radicals which deplete the ozone layer.

Q. 51. What are Polar Stratospheric Clouds (PSCs) ?

Ans. The special types of clouds present over Antarctica in winter are called Polar Stratospheric Clouds.

Q. 52. In which season the depletion of ozone on Antarctica takes place and when is it replenished ?

Ans. During spring season (*i.e.* in the months of September and October), depletion of ozone takes place and after spring (*i.e.* in the month of November), it is replenished.

Q. 53. What is Polar Vortex ? What is its effect ?

Ans. A tight whirlpool of wind formed in the stratosphere which surrounds Antarctica is called Polar Vortex.

Q. 54. What should be the tolerable limit of fluoride ions in drinking water ? What happens if it is higher than 10 ppm ?

Ans. 1 ppm or 1 mg dm^{-3}. Higher concentration is harmful to bones and teeth.

Q. 55. Name any four methods for waste management.

Ans. Recycling, Burning and Incineration, Sewage treatment and Dumping.

Q. 56. Name three methods generally used in green chemistry.

Ans. Use of sunlight and microwaves, use of sound waves and use of enzymes.

Q. 57. Give three examples in which green chemistry has been applied.

Ans. Synthesis of Ibuprofen, dehydrogenation of diethanolamine for production of herbicide and replacement of chlorofluorocarbons (CFC's) by CO_2 as blowing agent.

Short Answer Questions CARRYING 2 or 3 MARKS

Sec. 18.1. **1.** Write about the structure of different regions of the atmosphere.

2. What are hydrosphere, lithosphere and biosphere ?

3. Define 'environmental chemistry' and 'environmental science'.

Sec. 18.2. **4.** Define environmental pollution. List three episodes of recent past of environmental pollution.

Sec. 18.3. **5.** What are primary and secondary pollutants ?

6. What are biodegradable and non-biodegradable pollutants ?

Sec. 18.4. **7.** Depending upon the nature of pollutant, how can the pollution be classified into different types ?

Sec. 18.5. **8.** What is the composition of pure dry air ? What do you mean by the terms 'sink' and 'target' with respect to pollution.

Sec. 18.6. **9.** List three natural sources and five man-made sources responsible for air pollution.

Sec. 18.7. **10.** What are the main air pollutants ? Write about the sources and harmful effects of any one of them.

11. How carbon monoxide acts as a poison for human beings ?

12. What remedial steps should be taken to save a person suffering from CO pisoning ?

13. What are sources and sinks of nitrogen oxides as air pollutant ? What are their effects ?

14. How can pollution due to nitrogen oxides be controlled ?

15. What are sources and sinks of sulphur oxide pollution ?

16. How can SO_x pollution be controlled ?

17. What are particulates ? What are their sources ?

18. How lead halides enter into atmosphere as pollutants ?

19. What are the harmful effects of particulate pollutants ? List at least five of them.

20. Briefly explain 'Electrostatic precipitation' method for controlling particulate pollution.

21. What are the pollutants attacking Taj Mahal ? How are they being produced in the atmosphere ?

Sec. 18.8. **22.** List ten industries responsible for causing air pollution.

Sec. 18.9. **23.** What chemical reactions are occurring in the stratosphere ?

24. How NO is depleting ozone layer ?

25. How are 'freons' creating a hole in the ozone layer ?

26. What are the reactions occurring in the mesosphere ?

Sec.18.10. **27.** How ozone layer is formed and acting as a protecting umbrella ?

28. What are the factors responsible for depletion of ozone layer ? What are the chemical reactions involved ?

29. What do you understand by ozone hole ? Why does it occur mainly over Antarctica ? *(N.C.E.R.T.)*

30. What do you understand by *(i)* polar stratospheric clouds *(ii)* polar vortex ? *(N.C.E.R.T.)*

Sec.18.11. **31.** List the main points of difference between 'London smog' and 'Photochemical smog'.

32. What is 'Los Angeles smog' ? How is it produced in the atmosphere ?

Sec.18.12. **33.** What is 'Acid Rain' ? What are its harmful effects ?

or What is the cause of acid rain ? How is it harmful to the environment ? *(N.C.E.R.T.)*

Sec.18.13. **34.** What is 'Greenhouse effect' ? How does it affect the global climate ?

35. Why does Greenhouse effect lead to the global warming ? What could be the consequences of global warming ? *(N.C.E.R.T.)*

Sec. 18.14 to 18.15. **36.** What is ground water pollution ? How does it take place ?

37. How is the pollution of river water caused ? Which plans have been made by Government of India so as to stop this pollution ?

38. What is 'marine pollution' ? What are the sources of oil pollution in sea water ?

39. What are the effects of oil pollution in sea water ?

Sec. 18.16. 40. List at least five important sources responsible for water pollution. *(N.C.E.R.T.)*

Sec. 18.17. 41. What are the main inorganic and organic pollutants present in water ?

42. How synthetic detergents present as water pollutant create problems ?

43. What are oxygen-demanding wastes ? Define 'BOD_5'. How is it determined ?

44. Discuss the importance of dissolved oxygen in water. What processes are generally responsible for the deoxygenation of water ? *(N.C.E.R.T.)*

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

46. How plant nutrients and pesticides act as water pollutants ? *(N.C.E.R.T.)*

47. What are thermal pollutants ? What are their sources ? What damage is done by them ?

Sec. 18.19 to 18.20. 48. Which soil is considered as best soil for most of the crops ? What is its composition ?

49. Name at least four soil pollutants. Explain one of them.

Sec. 18.21. 50. What are the different sources of soil pollution ? Name the pollutants being added by them.

Sec. 18.22 to 18.23. 51. Comment on the statement—Green chemistry is an alternative tool for reducing pollution.

52. Give some examples of the achievements of green chemistry.

Long Answer Questions CARRYING 5 or more MARKS

Sec 18.1. 1. What are the main components of our environment ? Explain each of them briefly.

2. What are the different regions of the atmosphere ? Explain each of them briefly.

3. What is Environmental chemistry ? Discuss its social relevance. *(N.C.E.R.T.)*

Sec 18.2 to 18.4. 4. Quote three incidents which proved disastrous due to environmental pollution. How can you classify environmental pollutants and environmental pollution into different types ?

5. Define an environmental pollutant. What do you understand by an environmental pollution model ? *(N.C.E.R.T.)*

Sec. 18.5 to 18.6. 6. What is Air pollution ? What are the main sources of air pollution ? Write a few lines about each of them.

Sec. 18.7. 7. What are major air pollutants ? Briefly explain any two of them.

8. Describe sources of pollution, sinks, harmful effects and methods to control the following pollutants : CO, NO_x and SO_x.

9. Describe briefly the hydrocarbons and particulates as pollutants.

10. Briefly explain different methods used to control particulate pollutants.

11. What do you understand by *(i)* Mists *(ii)* Smoke *(iii)* Fumes and *(iv)* Dust ? *(N.C.E.R.T.)*

Sec. 18.8. 12. Write a short note on "Industrial Air Pollution".

Sec. 18.9. 13. Explain the reactions occurring in different regions of the atmosphere.

Sec. 18.10. 14. Explain the formation and depletion of "ozone layer." What are the effects of depletion of this layer ?

Sec 18.11. 15. Name two different types of "smog". Explain briefly how are they formed ?

16. What are smogs ? Distinguish between classical and photochemical smogs. *(N.C.E.R.T.)*

17. How is photochemical smog formed ? What are its effects ? How can it be controlled ? *(N.C.E.R.T.)*

Sec 18.12. 18. Write an explanatory note on "Acid Rain."

Sec. 18.13. 19. What is "Greenhouse effect" ? Why is it so called ? What are its consequences ?

Sec 18.14 to 18.18. 20. How can you classify water pollution into different types ? Briefly explain each one of them.

21. What are the international standards for drinking water ?

22. How can you classify water pollutants into different types ? Briefly explain each one of them.

23. What do you understand by BOD and COD ? How are these determined ? *(N.C.E.R.T.)*

Sec. 18.19 to 18.21. 24. What is "soil" ? What is its composition ? What are the sources of soil pollution ?

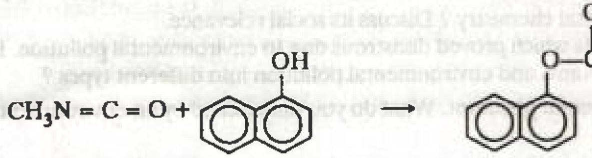
Sec. 18.22 to 18.23. 25. Explain the strategy that has been adopted to control environmental pollution.

COMPETITION FOCUS

ADDITIONAL USEFUL INFORMATION

1. How Bhopal Gas Tragedy occurred ? Methyl isocyanate is produced by reaction between methyl amine and phosgene which is further used for the manufacture of the insecticide called *carbaryl* (or commercial name—*sevin*) by reaction with 1—naphthol as follows :

$$CH_3NH_2 + COCl_2 \longrightarrow \underset{\text{MIC}}{CH_3{-}N = C = O} + 2\,HCl$$



The pressure inside one of the tanks containing MIC rose to such a high level that it blasted the release valve and as a result MIC escaped into the atmosphere. The reason for the sudden rise of pressure is believed to be the entry of some moisture into the tank that must have resulted into the following exothermic hydrolysis reaction

$$CH_3{-}N = C = O + H_2O \longrightarrow CH_3NH_2 + CO_2$$

2. How CO links to haemoglobin ? In haemoglobin, Fe (II) atom is coordinated to five groups and the sixth site is free. Normally O_2 links to Fe (II) at this sixth co- ordination site but CO is a stronger ligand than O_2, therefore if CO is present, it occupies the vacant co- ordination site and not O_2.

3. Reasons for fall or rise of temperature in different regions of the atmosphere. In *troposphere,* the fall in temperature with altitude is due to fall of pressure and density of air. In *stratosphere*, the rise in temperature with altitude is due to absorption of solar ultraviolet radiation by ozone. In *mesosphere*, decrease in temperature is due to low absorption of ultraviolet radiations by ozone.

4. Other green house gases. Though CO_2 is the key gas in the greenhouse effect but there are some other greenhouse gases also *e.g.* methane, chlorofluorocarbons, ozone, nitrous oxide and water vapour. Their relative contributions are as follows : CO_2 (50%), CH_4 (19%), CFC (17%), O_3 (8%), N_2O (4%), H_2O (2%).

5. Eutrophication. The presence of excessive nutrients in a lake due to inflow (land run-off) of nutrients from fertilizers results in the increase of phosphate ions in water. As a result, the formation of algae is accelerated and the concentration of dissolved oxygen decreases. This process is called eutrophication. Consequently, aquatic life is adversely affected. The fish start perishing.

6. Ecosystem. The co-existence of **biotic components** (living organisms) *i.e.* animals, plants and microorganisms and **abiotic components** (non-living materials or factors) which may be inorganic (*e.g.* CO_2, N_2, S, P etc.) or organic (*e.g.* proteins, carbohydrates etc.) and climatic factors (like temperature, humidity etc.) is called an ecosystem.

C.B.S.E.-P.M.T. (MAINS) SPECIAL

Q. 1. Explain the difference between a contaminant and a pollutant.

Ans. Refer to page 18/4.

Q. 2. What is Pneumoconiosis ? How does it occur ? (N.C.E.R.T.)

Ans. Pneumoconiosis is a disease of lungs such as lung cancer, bronchital asthma, chronic bronchitis etc. It is caused by small sized particulates which enter into lung through nose and provide a large surface area for adsorption of carcinogenic compounds such as polynuclear hydrocarbons, asbestos etc.

Q. 3. The depletion of ozone layer occurs over Antarctica during spring time and it gets replenished after spring time. Explain. (N.C.E.R.T.)

Ans. Refer to page 18/16.

Q. 4. What do you understand by Greenhouse effect ? What are the major Greenhouse gases ? (N.C.E.R.T.)

Ans. The warming of the the earth or global warming due to re-emission of sun's energy absorbed by the earth followed by its absorption by CO_2 molecules and H_2O vapour present near the earth's surface and then its radiation back to the earth is called greenhouse effect.

Though CO_2 is the main gas in the greenhouse effect, there are some other greenhouse gases also eg. methane, chlorofluorocarbons, ozone, nitrous oxide and water vapours.

Q. 5. What is COD ? Why is it preferred over BOD ? How is it determined ?

Ans. COD stands for Chemical Oxygen Demand. It is preferred over BOD (Biochemical Oxygen Demand) because BOD takes a number of days *e.g.* BOD_5 takes 5 days whereas COD can be determined in a very short time. For method of determination of COD, refer to page 18/24.

Q. 6. Explain the term 'Eutrophication'.

Ans. Refer to page 18/34.

MULTIPLE CHOICE QUESTIONS

For CBSE– PMT (Preliminary), IIT Screening, AIEEE, AIIMS, AFMC, DPMT, CPMT, BHU and All Other Competitive Examinations

1. Which of the following is the uppermost region of the atmosphere ?
(*a*) Stratosphere (*b*) Troposphere
(*c*) Exosphere (*d*) Ionosphere

2. Which of the following is the coldest region ?
(*a*) Troposphere (*b*) Mesosphere
(*c*) Stratosphere (*d*) Thermosphere

3. Which of the following is a secondary pollutant ?
(*a*) NO (*b*) CO
(*c*) SO_2 (*d*) PAN

4. Which of the following is not considered to be a pollutant ?
(*a*) NO_2 (*b*) CO_2
(*c*) O_3 (*d*) C_xH_y

5. Which of the following has greatest affinity for haemoglobin ?
(*a*) CO (*b*) NO
(*c*) O_2 (*d*) CO_2

6. The most abundant hydrocarbon pollutant is
(*a*) Methane (*b*) Ethane
(*c*) Propane (*d*) Butane

7. Which of the following is not involved in formation of photochemical smog ?
(*a*) NO (*b*) O_3
(*c*) C_xH_y (*d*) SO_2

8. The size of particulates of H_2SO_4 fog lies in the range
(*a*) 5—100 *nm*
(*b*) 100—500 *nm*
(*c*) 500—1000 *nm*
(*d*) 1000—10,000 *nm*

ANSWERS

1. *c* **2.** *b* **3.** *b* **4.** *b* **5.** *b* **6.** *a* **7.** *d* **8.** *c*

9. The aromatic compounds present as particulates are

(*a*) Benzene (*b*) Toluene

(*c*) Nitrobenzene

(*d*) Polycyclic hydrocarbons

10. 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

11. London smog is found in

(*a*) Summer during day time

(*b*) Summer during morning time

(*c*) Winter during morning time

(*d*) Summer during day time

12. Photochemical smog is formed in

(*a*) Summer during morning time

(*b*) Summer during day time

(*c*) Winter during morning time

(*d*) Winter during day time

13. Which of the following statement is false ?

(*a*) London smog is oxidising in nature

(*b*) London smog contains H_2SO_4 droplets

(*c*) London smog is formed in winter

(*d*) London smog causes bronchitis.

14. Which of the following is true about photochemical smog ?

(*a*) It is reducing in nature

(*b*) It is formed in winter

(*c*) It is a mixture of smoke and fog

(*d*) It causes irritation in eyes.

15. 'White lung cancer' is caused by

(*a*) asbestos (*b*) silica

(*c*) textiles (*d*) paper

16. Ozone layer is present in

(*a*) troposphere (*b*) stratosphere

(*c*) mesosphere (*d*) exosphere

17. Depletion of ozone layer causes

(*a*) blood cancer (*b*) lung cancer

(*c*) skin cancer (*d*) breast cancer

18. Which of the following is not a greenhouse gas ?

(*a*) CO_2 (*b*) CH_4

(*c*) chlorofluorocarbons (*d*) O_2

19. BOD_5 is

(*a*) waste decomposed in 5 days

(*b*) oxygen used in 5 days

(*c*) microorganisms killed in 5 days

(*d*) dissolved oxygen left after 5 days

20. In which region/regions of the atmosphere, temperature decreases with altitude ?

(*a*) Troposphere (*b*) Stratosphere

(*c*) Mesosphere (*d*) Thermosphere

21. The gas/es involved in the formation of photochemical fog are

(*a*) CO_2 (*b*) SO_2

(*c*) NO (*d*) hydrocarbons

22. Which of the following is/are correct about the size of particulates ?

(*a*) Soot particles have diameter of about 5 *nm*

(*b*) H_2SO_4 fog particles have size of 500 — 1000 *nm*

(*c*) Fly ash particles have diameter of 5×10^5 *nm*

(*d*) All particulates have same size

23. Choose the wrong statement/s

(*a*) CO_2 is responsible for greenhouse effect

(*b*) CO_2 can absorb infrafred radiation but does not allow them to pass through

(*c*) NO is more harmful than NO_2

(*d*) Acid rain contains mainly HNO_3.

24. Ozone in the stratosphere is deleted by

(*a*) CF_2Cl_2 (*b*) C_7F_{16}

(*c*) $C_6H_6Cl_6$ (*d*) C_6F_6

(A.I.I.M.S. 2004)

25. 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.

(C.B.S.E. P.M.T. 2004)

26. The smog is essentially caused by the presence of

(*a*) O_2 and O_3 (*b*) O_2 and N_2

(*c*) Oxides of sulphur and nitrogen

(*d*) O_3 and N_2 *(A.I.E.E.E. 2004)*

ANSWERS

9. *d* **10.** *b* **11.** *c* **12.** *b* **13.** *a* **14.** *d* **15.** *c* **16.** *b* **17.** *c* **18.** *d*

19. *b* **20.** *a,c* **21.** *c,d* **22.** *a,b,c* **23.** *c,d* **24.** *a* **25.** *d* **26.** *c*

ADDITIONAL QUESTIONS

For All Competitive Examinations

Assertion-Reason Type Questions

The questions given below consist of an "Assertion" in column 1 and the "Reason" in column 2. 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 assertion and reason are FALSE.

	Assertion	**Reason**
1.	The temperature in the stratosphere increases with altitude.	Ozone present absorbs the ultraviolet radiation.
2.	Photochemical smog is a combination of photons with smoke and fog.	Photons, smoke and acid fog are present in the atmosphere.
3.	For greenhouse effect, presence of green plants is essential.	Chlorophyll of the green plants causes greenhouse effect.
4.	CO and NO both combine with haemoglobin.	Both have equal affinity for haemoglobin.

True/False Statements

Choose the false statements out of the following and rewrite them correctly.

1. Mesosphere and thermosphere are collectively called ionosphere.
2. Tropopause exists at a height of about 11 km.
3. CO causes death because it is converted into CO_2 inside the body.
4. NO is more poisonous than NO_2.
5. CO_2 is not considered as pollutant of the atmosphere.
6. Presence of hydrocarbons is essential for photochemical fog formation.
7. Acid rain does not contain HCl acid.
8. London smog is formed in summer.
9. Photochemical smog is oxidizing in nature.
10. Greenhouse effect is only due to CO_2 gas.
11. NO has greater affinity for haemoglobin than CO.
12. Ozone layer is being depleted because it is dissociated into O_2 and O-atoms by ultraviolet rays.

Fill In The Blanks

1. The uppermost region of the atmosphere is known as........ .
2. Ozone layer is depleted by........ and ....
3. Acid rain contains........, ...and........acids.
4. CO_2 and H_2O vapour can absorb........radiation.
5. Slowing down of the formation of chlorophyll in presenceof SO_2 is called........ .
6. The enrichment of nutrients due to land run-off of nutrients into lake is called........ .
7. The lung disease caused by asbestos is called....... .
8. The lung disease caused by silica is called........ .
9. The main participlants in photochemical smog formation are........ and........ .
10. Photochemical smog is formed in........during....... time.
11. London smog is........in nature.
12. Pollution of sea water is called........ .
13. Depletion of ozone layer takes place mainly over........ .
14. COD is found by using........ .
15. The depletion of ozone over Antarctica takes place in........season.
16. The tight whirlpool of wind formed in the stratosphere which surrounds Antarctica is known as.... .

Matching Type Questions

Match the entries of column A with appropriate entries of column B.

Column A	Column B
1. Greenhouse effect	1. CO
2. Depletion of ozone layer	2. C_xY_y
3. Photochemical smog	3. NO
4. Acid rain	4. SO_2
5. Combination with haemoglobin	5. CO_2

ANSWERS

ASSERTION-REASON TYPE QUESTIONS

1. (*a*) 2. (*d*) 3. (*e*) 4. (*c*).

TRUE/FALSE STATEMENTS

3, 4, 7, 8, 10, 12.

FILL IN THE BLANKS

1. exosphere 2. NO, chlorofluorocarbons (freons) 3. H_2SO_4, HNO_3, HCl 4. infrared 5. chlorosis 6. eutrophication 7. asbestosis 8. silicosis 9. NO, hydrocarbons 10. summer, afternoon 11. reducing 12. marine pollution 13. Antarctica 14. Acidified $K_2Cr_2O_7$ 15. spring 16. Polar vortex.

MATCHING TYPE QUESTIONS

1—5, 2—3, 3—2, 4—4, 5—1.

APPENDIX 1

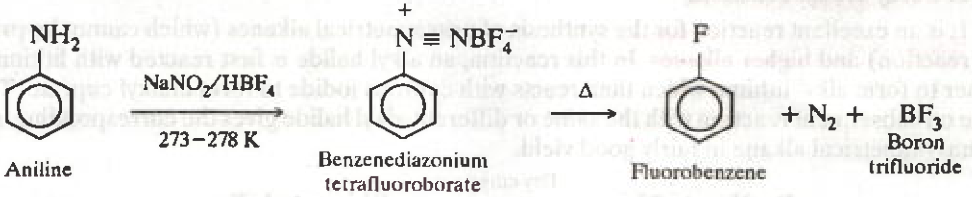
Important Name Reactions

(In Alphabetical Order)

1. Balz-Schiemann reaction.

(P.S.B. 2001)

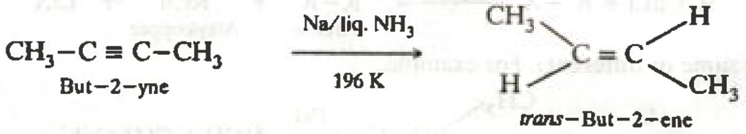
Fluoroarenes (aryl fluorides) cannot be prepared by direct fluorination of aromatic hydrocarbons since the reaction is very violent and cannot be easily controlled. These can, however, be easily prepared by *Balz-Schiemann reaction.* In this reaction, the aromatic primary amine is first diazotised with $NaNO_2$ in presence of HBF_4 (fluoroboric acid) at 273-278 K and the aryldiazonium tetrafluoroborate thus formed is heated to give the corresponding aryl fluoride. For example,



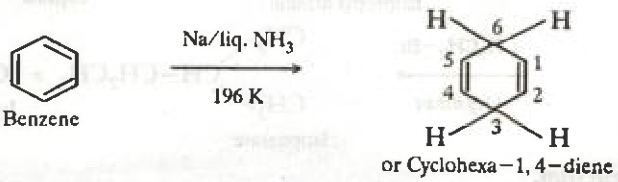
This reaction is called **Balz-Schiemann reaction.**

2. Birch reduction.

Reduction of unsaturated compounds (alkenes, alkynes and arenes) with active metals such as Li, Na, K etc. in liquid ammonia is called **Birch reduction.** The product formed, however depends upon the nature of the starting material. For example,



This reduction is stereoselective and gives only the *trans*- addition product. In arenes, 1, 4-addition of hydrogen atoms occurs. For example,



3. Birnbaum-Simonini reaction.

When silver salt of a fatty acid is heated with I_2 in CCl_4, it gives an ester instead of iodoalkane (*cf.* Hunsdiecker reaction). For example,

$$\underset{\text{Silver acetate}}{2\,CH_3COOAg} + I_2 \xrightarrow[\Delta]{CCl_4} \underset{\text{Methyl acetate}}{CH_3COOCH_3} + CO_2 + 2\,AgI$$

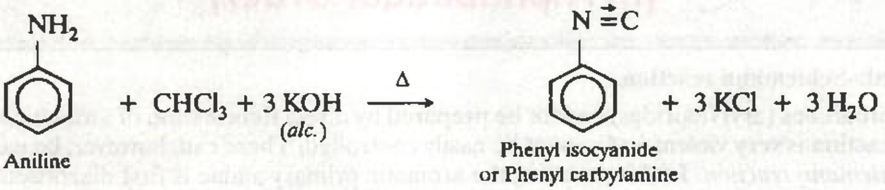
This is called **Birnbaum-Simonini reaction.**

4. Carbylamine reaction.

(*H.P.S.B. 1996, 2000 ; H.S.B. 2000, 2001 ; A.I.S.B. 1996, 2003 ; P.S.B. 1997, 2000, 2001, 2003*)

When a primary amine (*aliphatic or aromatic*) is warmed with chloroform and alcoholic KOH, it forms an isocyanide or carbylamine having offensive smell. This reaction is called *carbylamine reaction.* For example,

$$\underset{\text{Ethylamine}}{CH_3CH_2NH_2} + CHCl_3 + \underset{(alc.)}{3\,KOH} \xrightarrow{\Delta} \underset{\substack{\text{Ethyl isocyanide}\\ \text{or Ethyl carbylamine}}}{CH_3CH_2N \overset{\rightarrow}{=} C} + 3KCl + 3\,H_2O$$



Since secondary and tertiary amines (aliphatic or aromatic) do not give this reaction, it is used as a test for primary amines and also for the distinction of primary amines from secondary and tertiary amines.

5. Corey-House reaction.

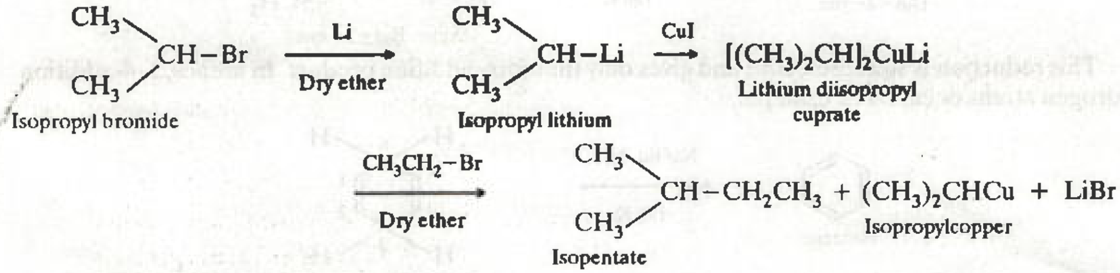
It is an excellent reaction for the synthesis of unsymmetrical alkanes (which cannot be prepared by Wurtz reaction) and higher alkanes. In this reaction, an alkyl halide is first reacted with lithium metal in dry ether to form alkyl lithium which then reacts with cuprous iodide to form dialkyl cuprate. The dialkyl cuprate on subsequent reaction with the same or different alkyl halide gives the corresponding symmetrical or unsymmetrical alkane in fairly good yield.

$$\underset{\text{Alkyl halide}}{R-X} + 2\,Li \xrightarrow{\text{Dry ether}} \underset{\text{Alkyl lithium}}{RLi} + LiX$$

$$2\,RLi + CuI \xrightarrow{\text{Dry ether}} \underset{\text{Lithium dialkylcuprate}}{R_2CuLi} + LiI$$

$$R_2CuLi + R'-X \xrightarrow{\text{Dry ether}} \underset{\text{Alkane}}{R-R'} + \underset{\text{Alkylcopper}}{RCu} + LiX$$

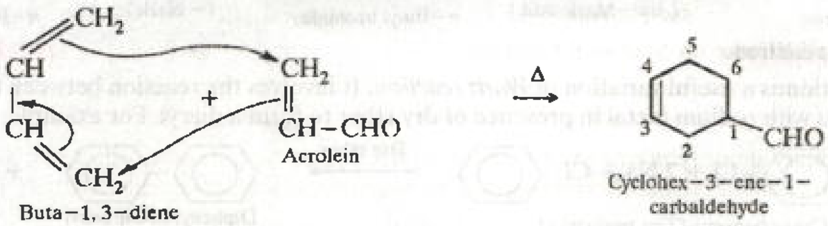
(R, R′ may be same or different). For example,

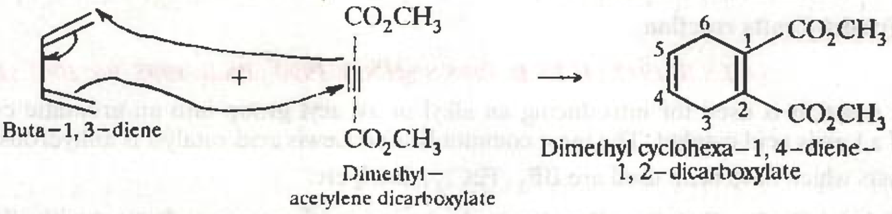


6. Diels-Alder reaction.

It involves the addition of a **conjugated diene** (*4π-electron system*) to an unsaturated compound (alkene or alkyne) containing an electron-withdrawing group (*2π-electron system*) usually called **dienophile** (diene loving) to form six-membered cyclic alkenes (*usually called Diels Alder adducts*). These reactions are called commonly referred to as **[4 + 2] cycloaddition reactions** since in these reactions, a

4π-electron system adds to a 2π-electron system. Diels-Alder reactions normally do not need any catalysts and generally occur on heating. For example,



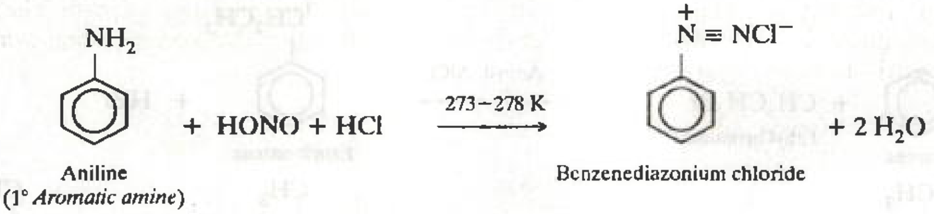


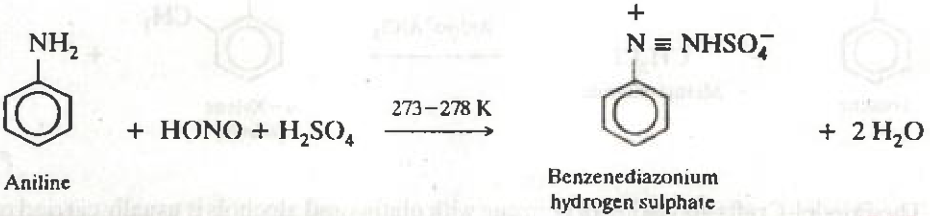
7. Diazotisation reaction.

(H.P.S.B. 1989 S, 91, 93, 95, 97 ; H.S.B. 1995, 2001 ; P.S.B. 2001)

When a cold solution of a primary aromatic amine in a dilute mineral acid (HCl or H_2SO_4) is treated with a cold solution of nitrous acid (generated *in situ* by the action of dil. HCl or dil. H_2SO_4 on $NaNO_2$) at 273 – 278 K, arenediazonium salt is formed. This reaction is called *diazotisation reaction* For example.

$$NaNO_2 + HCl \longrightarrow HONO + NaCl$$





8. Finkelstein reaction.

(P.S.B. 2001)

Iodoalkanes can be easily prepared from the corresponding chloro- or bromoalkanes by heating with sodium iodide in acetone or methanol.

$$\underset{\text{Bromoethane}}{CH_3CH_2-Br} + NaI \xrightarrow[\Delta]{\text{Acetone or methanol}} \underset{\text{Iodoethane}}{CH_3CH_2-I} + NaBr$$

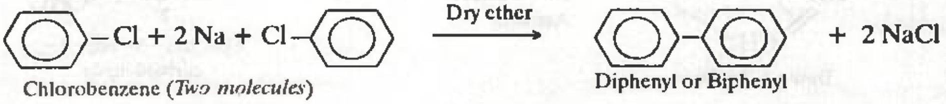
This reaction is called **Finkelstein reaction.** The driving force for this reaction is the fact that NaBr (or NaCl in case of chloroalkanes) is less soluble than NaI in acetone or methanol and thus gets deposited during the reaction. As a result, equilibrium shifts in the forward direction. This reaction is very useful for preparing such alkyl iodides which cannot be prepared by direct addition of HI to alkenes. For example, *n*-butyl iodide cannot be prepared by direct addition of HI to 1-butene. However, this can be prepared from 1-butene using Finkelstein reaction as shown below :

$$\underset{\text{1-Butene}}{CH_3CH_2CH=CH_2} \xrightarrow[\text{(Anti-Mark. add.)}]{\text{HBr, peroxide}} \underset{n\text{-Butyl bromide}}{CH_3CH_2CH_2CH_2Br} \xrightarrow[\text{(- NaBr)}]{\text{NaI/acetone, }\Delta} \underset{n\text{-Butyl iodide}}{CH_3CH_2CH_2CH_2I}$$

9. Fittig reaction.

(P.S.B. 2000, 2001)

This rection is a useful variation of *Wurtz reaction*. It involves the reaction between two molecules of an aryl halide with sodium metal in presence of dry ether to form a diaryl. For example,

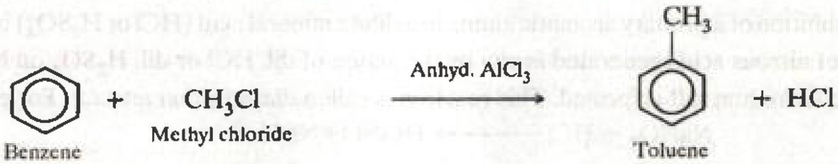


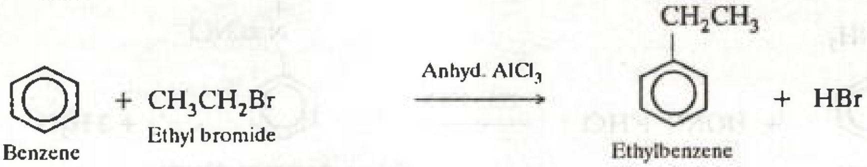
10. Friedel-Crafts reaction.

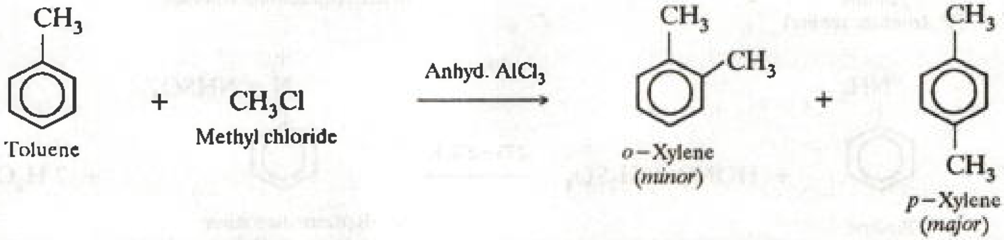
(A.I.S.B. 1987 ; H.P.S.B. 1988 S ; H.S.B. 1990 ; P.S.B. 1995, 96, 2001 ; D.S.B. 2003)

This reaction is used for introducing an alkyl or an acyl group into an aromatic compound in presence of a Lewis acid catalyst. The most commonly used Lewis acid catalyst is anhydrous $AlCl_3$ while other catalysts which have been used are BF_3 , $FeCl_3$, $SnCl_4$ etc.

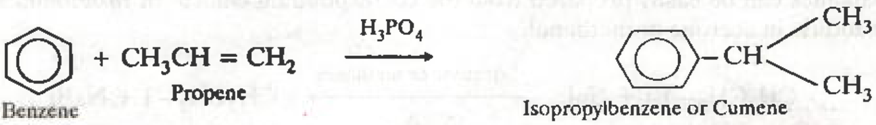
(*a*) **Friedel-Crafts alkylation.** Benzene and other aromatic compounds react with alkyl halides in presence of anhydrous aluminium chloride to form alkylbenzenes. For example,







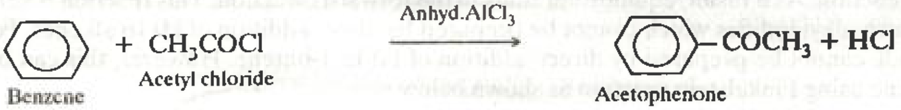
The Friedel-Crafts alkylation of benzene with olefins and alcohols is usually carried out in presence of protonic acids such as HF, H_2SO_4 or H_3PO_4 . For example

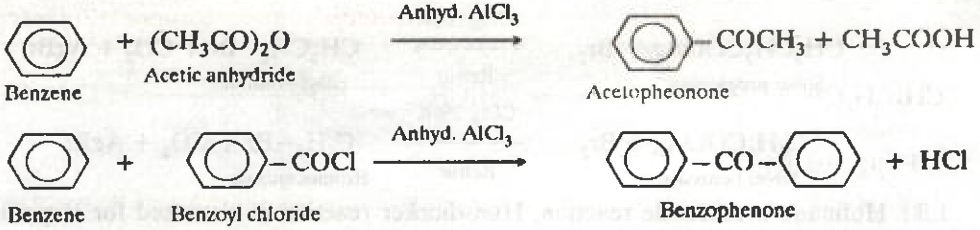


(*b*) **Friedel-Crafts acylation.**

(H.S.B. 2001 ; P.S.B. 2001)

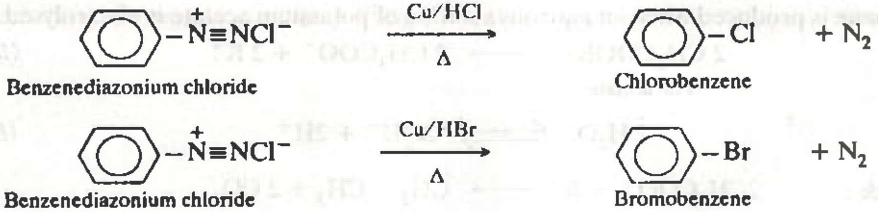
Benzene and other aromatic compounds react with acid chlorides or anhydrides in presence of anhyd. $AlCl_3$ to form ketones. For example,





11. Gattermann reaction. *(A.I.S.B. 1990 S ; P.S.B. 2002)*

This is a modification of *Sandmeyer reaction* in which benzenediazonium chloride is treated with copper powder and a halogen acid (instead of cuprous halide dissolved in the corresponding halogen acid) to form aryl halides. For example,



The yields are around 40%

12. Haloform reaction (Iodoform reaction). *(P.S.B. 1995, 2001, 2002)*

All compounds containing the grouping CH_3CHOH- (*i.e. methylcarbinols* such as ethanol, 2-propanol, 2-butanol etc.) or CH_3CO- (*i.e. methyl ketones* such as propanone, butanone, 2-pentanone, acetophenone etc.) when treated with a halogen and excess of alkali (*i.e.* sodium hypohalite, NaOX) form haloforms. If the halogen used is iodine, yellow precipitate of iodoform is formed and the reaction is called *iodoform reaction.* For example,

$$\underset{\text{Ethanol}}{CH_2CH_2OH} + 4I_2 + 6\,NaOH \longrightarrow \underset{\text{Iodoform}}{CHI_3} + + HCOONa + 5\,NaI + 5\,H_2O$$

$$\underset{\text{2-Propanol}}{CH_3CHOHCH_3} + 4I_2 + 6\,NaOH \longrightarrow \underset{\text{Iodoform}}{CHI_3} + CH_3COONa + 5\,NaI + 5\,H_2O$$

$$\underset{\text{Propanone}}{CH_3COCH_3} + 3I_2 + 4\,NaOH \longrightarrow \underset{\text{Iodoform}}{CHI_3} + CH_3COONa + 3\,NaI + 3H_2O$$

$$\underset{\text{2-Butanone}}{CH_3COCH_2CH_3} + 3I_2 + 4\,NaOH \longrightarrow \underset{\text{Iodoform}}{CHI_3} + CH_3CH_2COONa + 3\,NaI + 3\,H_2O$$

$$\underset{\text{Acetophenone}}{C_6H_5COCH_3} + 3\,I_2 + 4\,NaOH \longrightarrow \underset{\text{Iodoform}}{CHI_3} + C_6H_5COONa + 3\,NaI + 3\,H_2O$$

Iodoform reaction is widely used for the distinction of methylcarbinols and methyl ketones from other alcohols and ketones.

13. Hunsdiecker reaction. *(P.S.B. 2000, 2001, 2002)*

The decomposition of the silver salt of a carboxylic acid with Br_2 in refluxing CCl_4 to form an alkyl or aryl bromide with one carbon less than the original acid is called *Hunsdiecker reaction* For example,

$$RCOOAg + Br_2 \xrightarrow[\text{Reflux}]{CCl_4,\ 350K} R-Br + CO_2 + AgBr$$

$$\underset{\text{Silver propionate}}{CH_3CH_2COOAg} + Br_2 \xrightarrow[\text{Reflux}]{CCl_4,\ 350K} \underset{\text{Ethyl bromide}}{CH_3CH_2-Br} + CO_2 + AgBr$$

$$\underset{\text{Silver benzoate}}{C_6H_5COOAg} + Br_2 \xrightarrow[\text{Reflux}]{CCl_4,\ 350K} \underset{\text{Bromobenzene}}{C_6H_5-Br} + CO_2 + AgBr$$

Like Hofmann bromamide reaction, Hunsdiecker reaction is also used for stepping down the homologous series.

14. Kolbe electrolytic reaction.

(A.I.S.B. 1988 ; D.S.B. 1989, 92 93 ; H.P.S.B. 2003)

This reaction is used to prepare some alkanes, alkenes and alkynes by electrolysis of aqueous solution of sodium or potassium salt of suitable acids. For example,

(*a*) **Ethane is produced when an aqueous solution of potassium acetate is electrolysed.**

$$\underset{\text{Pot. acetate}}{2\,CH_3COOK} \longrightarrow 2\,CH_3COO^- + 2\,K^+ \qquad (\textit{Ionization})$$

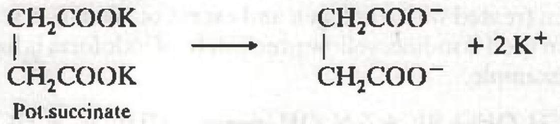
$$2\,H_2O \rightleftharpoons 2OH^- + 2H^+ \qquad (\textit{Ionization})$$

At anode : $2CH_3COO^- - 2e^- \longrightarrow \underset{\text{Ethane}}{CH_3-CH_3} + 2\,CO_2$

At cathode : Both K^+ and H^+ are present but H^+ ions are preferentially discharged due to their lower discharge potential.

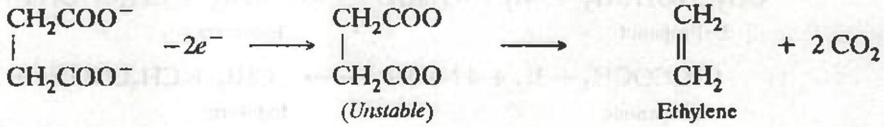
$$2H^+ + 2e^- \longrightarrow 2H^{\cdot} \longrightarrow H_2$$

(*b*) **Ethylene is produced when potassium salt of succinic acid is electrolysed.**



$$\underset{\text{Pot.succinate}}{\begin{array}{l}CH_2COOK\\ |\\ CH_2COOK\end{array}} \longrightarrow \begin{array}{l}CH_2COO^-\\ |\\ CH_2COO^-\end{array} + 2K^+ \qquad (\textit{Ionization})$$

$$2\,H_2O \rightleftharpoons 2OH^- + 2H^+ \qquad (\textit{Ionization})$$

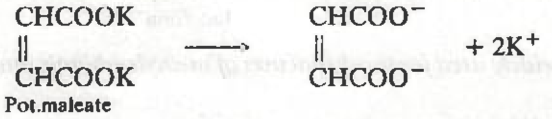


At anode : $\begin{array}{l}CH_2COO^-\\ |\\ CH_2COO^-\end{array} - 2e^- \longrightarrow \underset{(\textit{Unstable})}{\begin{array}{l}CH_2COO\\ |\\ CH_2COO\end{array}} \longrightarrow \underset{\text{Ethylene}}{\begin{array}{c}CH_2\\ \|\\ CH_2\end{array}} + 2\,CO_2$

At cathode : H_2 is produced as above

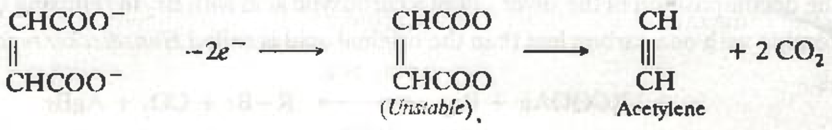
$$2H^+ + 2e^- \longrightarrow H_2$$

(*c*) **Acetylene is produced when potassium maleate or fumarate is electrolysed.**



$$\underset{\text{Pot.maleate}}{\begin{array}{l}CHCOOK\\ \|\\ CHCOOK\end{array}} \longrightarrow \begin{array}{l}CHCOO^-\\ \|\\ CHCOO^-\end{array} + 2K^+ \qquad (\textit{Ionization})$$

$$2\,H_2O \rightleftharpoons 2OH^- + 2H^+ \qquad (\textit{Ionization})$$



At anode : $\begin{array}{l}CHCOO^-\\ \|\\ CHCOO^-\end{array} - 2e^- \longrightarrow \underset{(\textit{Unstable})}{\begin{array}{l}CHCOO\\ \|\\ CHCOO\end{array}} \longrightarrow \underset{\text{Acetylene}}{\begin{array}{c}CH\\ |||\\ CH\end{array}} + 2\,CO_2$

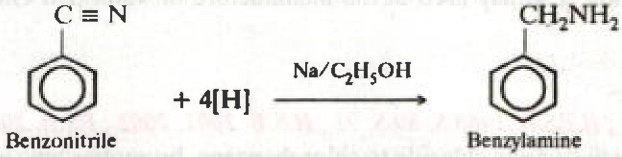
At cathode : H_2 is produced as above.

15. Mendius reaction.

(P.S.B. 2000, 2001, 2002 ; H.S.B. 2001, 2002)

The reduction of alkyl and aryl cyanides to primary amines with nascent hydrogen (produced by the action of sodium amalgam on alcohol) is called *Mendius reaction.* For example

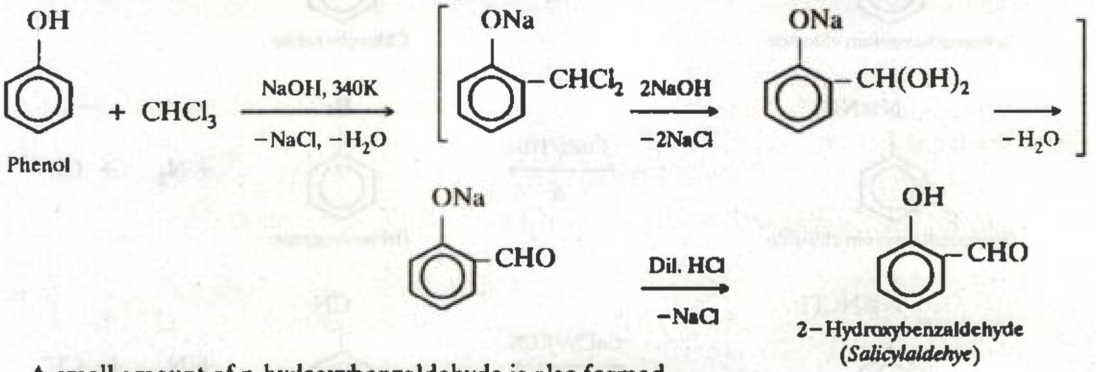
$$\underset{\text{Acetonitrile}}{CH_3C \equiv N} + 4[H] \xrightarrow{Na/C_2H_5OH} \underset{\text{Ethylamine}}{CH_3CH_2NH_2}$$



16. Reimer-Tiemann reaction.

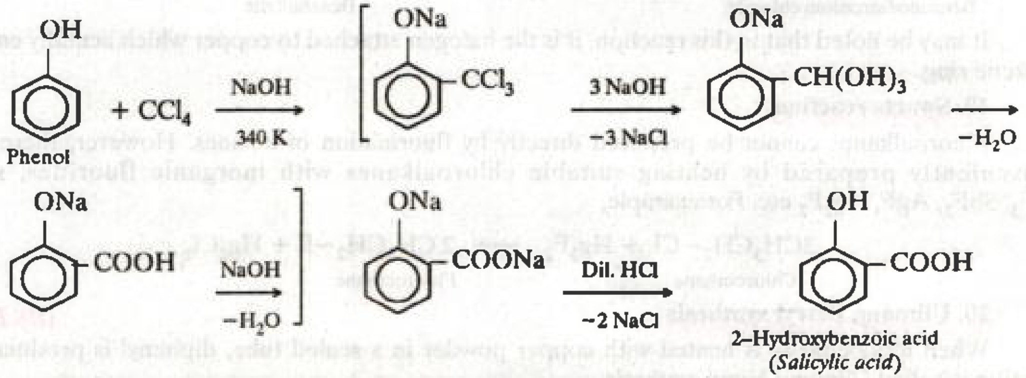
(A.I.S.B. 1985 ; H.P.S.B. 1988, 89, 92, 95 ; D.S.B. 2000 ; P.S.B. 2000, 2002, 2003)

Treatment of phenol with chloroform in presence of aqueous sodium or potassium hydroxide at 340 K followed by hydrolysis of the resulting product gives 2-hydroxybenzaldehyde (salicyladehyde). This reaction is called *Reimer-Tiemann reaction**.



A small amount of *p*-hydroxybenzaldehyde is also formed.

If instead of chloroform, **carbon tetrachloride** is used, salicylic acid is formed.



A small amount of *p*-hydroxybenzoic acid is also obtained.

17. Sabatier – Senderens reduction.

The reduction of unsaturated hydrocarbons to the corresponding saturated hydrocarbons with hydrogen in presence of nickel as catalyst at 523 – 573 K is called *Sabatier-Senderens reduction*. For example,

---

*This reaction is an example of an electrophilic substitution reaction in which the reactive electrophile is dichlorocarbene (:CCl_2).

$$\underset{\text{Ethylene}}{CH_2 = CH_2} + H_2 \xrightarrow[523-573\text{ K}]{\text{Ni}} \underset{\text{Ethane}}{CH_3 - CH_3}$$

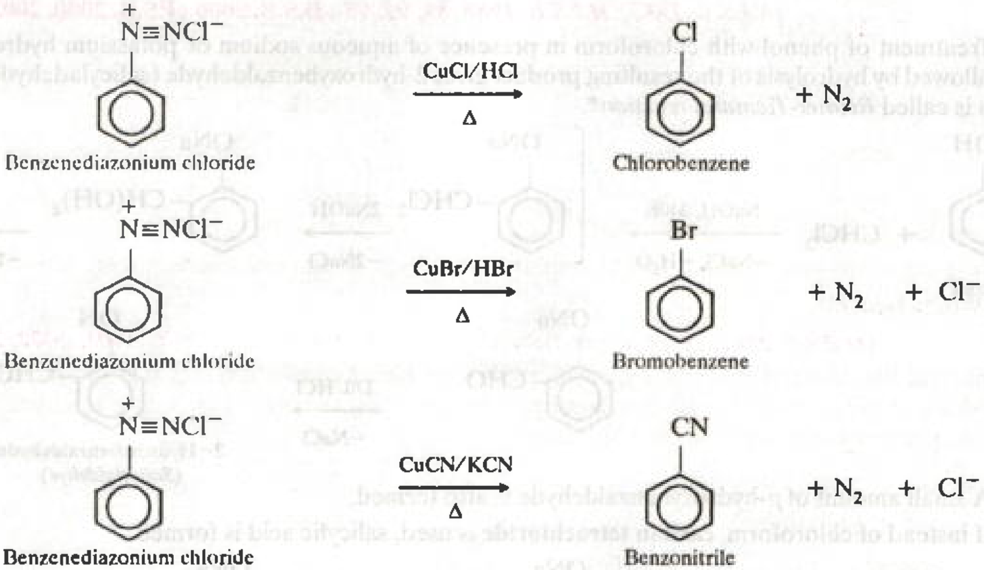
$$\underset{\text{Acetylene}}{CH \equiv CH} + 2H_2 \xrightarrow[523-573\text{ K}]{\text{Ni}} \underset{\text{Ethane}}{CH_3 - CH_3}$$

This catalytic hydrogenation is widely used in the manufacture of Vanaspati Ghee from edible vegetable oils.

18. Sandmeyer reaction.

(D.S.B. 1987, 96, 99 ; H.P.S.B. 1988 S, 89 S, 91 ; H.S.B. 2001, 2002 ; P.S.B. 2000, 2001, 2002)

The conversion of benzenediazonium chloride to chlorobenzene, bromobenzene and benzonitrile on treatment with CuCl/HCl. CuBr/HBr or CuCN/KCN respectively is called *Sandmeyer reaction*.



It may be noted that in this reaction, it is the halogen attached to copper which acutally enters the benzene ring.

19. Swarts reaction.

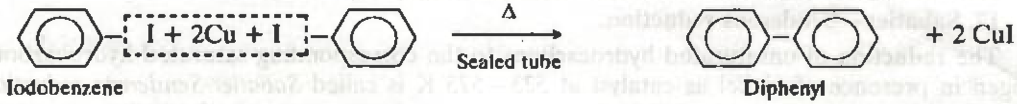
Fluoroalkanes cannot be prepared directly by fluorination of alkanes. However, these can be conveniently prepared by heating suitable chloroalkanes with inorganic fluorides, such as AsF_3, SbF_3, AgF, Hg_2F_2 etc. For example,

$$\underset{\text{Chloroethane}}{2CH_3CH_2-Cl} + Hg_2F_2 \longrightarrow \underset{\text{Fluoroethane}}{2\,CH_3CH_2-F} + Hg_2Cl_2$$

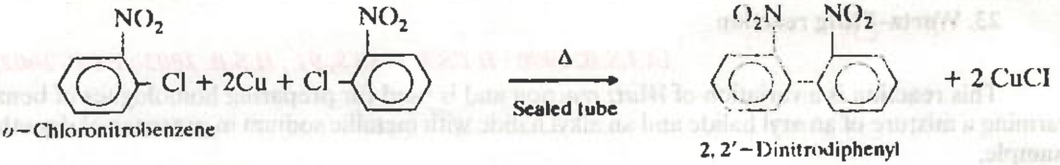
20. Ullmann Blaryl synthesis

(P.S.B. 2002)

When iodobenzene is heated with copper powder in a sealed tube, diphenyl is produced. This reaction is called *Ullmann biaryl synthesis*.



Aryl chlorides and aryl bromides usually do not react unless an electron-withdrawing group is present at *o*-and/or *p- position w.r.t.* the halogen atom. For example,



21. Williamson synthesis

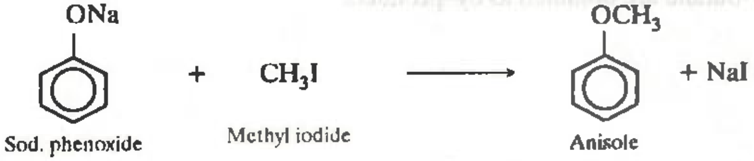
(H.P.S.B. 2001 ; A.I.S.B. 1997 ; P.S.B. 2000, 2001 ; H.S.B. 1999, 2001)

The reaction of alkyl halides with sodium alkoxide or sodium phenoxide to form ethers is called *Williamson synthesis*. For example,

$$\underset{\text{Alkyl halide}}{R-X} + \underset{\text{Sod. alkoxide}}{R'-ONa} \longrightarrow \underset{\text{Ether}}{R-O-R'} + NaX$$

$$\underset{\text{Methyl iodide}}{CH_3I} + \underset{\text{Sod. ethoxide}}{CH_3CH_2ONa} \longrightarrow \underset{\text{Ethyl methyl ether}}{CH_3-O-CH_2CH_3} + NaI$$

$$\underset{\text{Ethyl iodide}}{CH_3CH_2I} + \underset{\text{Sod. ethoxide}}{CH_3CH_2ONa} \longrightarrow \underset{\text{Diethyl ether}}{CH_3CH_2-O-CH_2CH_3} + NaI$$



This is one of the best methods for the preparation of both simple and mixed ethers.

22. Wurtz reaction

(H.P.S.B. 2001, H.S.B. 1990, 2001, 2002 ; D.S.B. 2002 ; P.S.B. 2000, 2001, 2002, 2003)

It involves the interaction of two molecules of an alkyl halide (preferably bromide or iodide) with metallic sodium in presence of dry ether to form symmetrical alkanes containing double the number of carbon atoms present in the alkyl halide. For example,

$$\underset{\text{Alkyl halide}}{R-X} + 2Na + X-R \xrightarrow{\text{Dry ether}} \underset{\text{Alkane}}{R-R} + 2NaX$$

e.g.,

$$\underset{\text{Methyl bromide}}{CH_3-Br} + 2Na + Br-CH_3 \xrightarrow{\text{Dry ether}} \underset{\text{Ethane}}{CH_3-CH_3} + 2NaBr$$

$$\underset{\text{Ethyl iodide}}{CH_3CH_2-I} + 2Na + I-CH_2CH_3 \xrightarrow{\text{Dry ether}} \underset{n\text{-Butane}}{CH_3CH_2-CH_2CH_3} + 2NaI$$

Thus, Wurtz reaction is a convenient method for the preparation of symmetrical alkanes (R−R), i.e. alkanes containing even number of carbon atoms.

However, if two different alkyl halides are used, a mixture of three alkanes is acutally obtained. For example,

$$\underset{\text{Methyl iodide}}{CH_3-I} + 2Na + \underset{\text{Ethyl iodide}}{I-CH_2CH_3} \xrightarrow{\text{Dry ether}} \underset{\text{Propane}}{CH_3-CH_2CH_3} + 2NaI$$

$$\underset{\text{Methyl iodide}}{CH_3-I} + 2Na + I-CH_3 \xrightarrow{\text{Dry ether}} \underset{\text{Ethane}}{CH_3-CH_3} + 2NaI$$

$$\underset{\text{Ethyl iodide}}{CH_3CH_2-I} + 2Na + I-CH_2CH_3 \xrightarrow{\text{Dry ether}} \underset{n\text{-Butane}}{CH_3CH_2-CH_2CH_3} + 2NaI$$

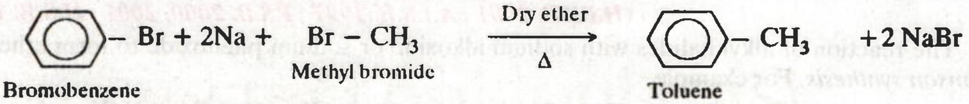
The boiling points of these alkanes are very close and hence cannot be separated by fractional distillation. That is why *Wurtz reaction is only useful for the preparation of symmetrical alkanes and not for the preparation of unsymmetrical alkanes, i.e. alkanes containing odd number of carbon atoms.*

23. Wurtz–Fittig reaction

(A.I.S.B. 1990 ; H.P.S.B 1988 S, 91 ; H.S.B. 2002 ; P.S.B. 2002, 2003)

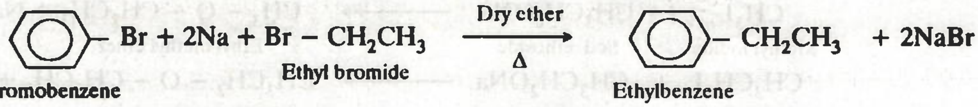
This reaction is a variation of *Wurtz reaction* and is used for preparing homologues of benzene by warming a mixture of an aryl halide and an alkyl halide with metallic sodium in presence of dry ether. For example,

(*i*)



Biphenyl and ethane are obtained as by-products

(*ii*)



Biphenyl and *n*-butane are obtained as by–products.

APPENDIX 2

Distinction Between Pairs of Compounds

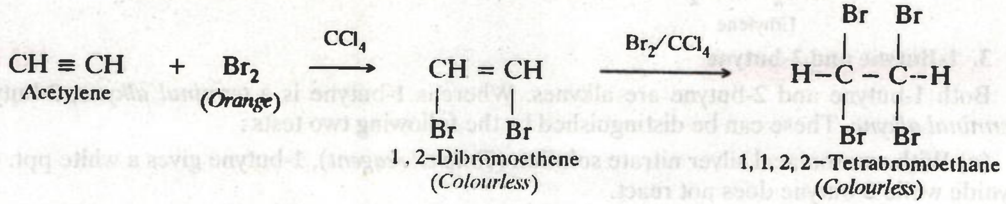
1. Methane (CH_4) and acetylene (C_2H_2)

(M.L.N.R. Allahabad 1995)

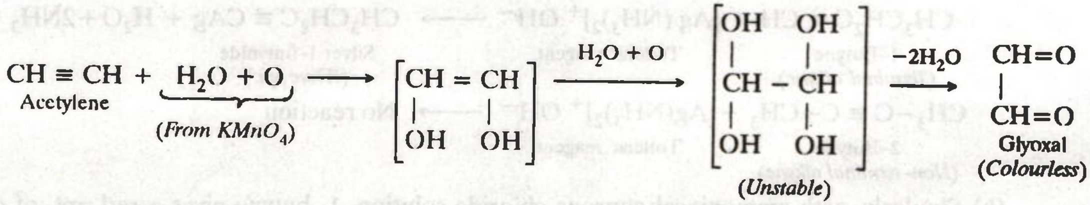
Methane is a *saturated hydrocarbon* while acetylene is an *unsaturated hydrocarbon*. These can be distinguished by the following tests :

(*a*) Methane being a saturated hydrocarbon does not decolourize Br_2 in CCl_4 as well as a cold dilute alkaline solution of $KMnO_4$ (*Baeyer's reagent*) while acetylene being an *unsaturated hydrocarbon* gives both these tests.

$$\underset{\text{Methane}}{CH_4} \xrightarrow{Br_2/CCl_4} \text{No action} \qquad \underset{\text{Methane}}{CH_4} \xrightarrow[(\textit{Baeyer's reagent})]{\text{Cold dil. alk. } KMnO_4 \text{ soln.}} \text{No action}$$



$$\underset{\text{Acetylene}}{CH\equiv CH} + \underset{(\textit{Orange})}{Br_2} \xrightarrow{CCl_4} \underset{\substack{\text{1, 2-Dibromoethene}\\ (\textit{Colourless})}}{\begin{array}{cc} CH = & CH\\ | & |\\ Br & Br\end{array}} \xrightarrow{Br_2/CCl_4} \underset{\text{1, 1, 2, 2-Tetrabromoethane}\atop (\textit{Colourless})}{\begin{array}{cccc} & Br & Br & \\ & | & | & \\ H- & C\ - & C- & H\\ & | & | & \\ & Br & Br & \end{array}}$$



$$\underset{\text{Acetylene}}{CH\equiv CH} + \underset{(\textit{From } KMnO_4)}{\underbrace{H_2O + O}} \longrightarrow \left[\begin{array}{cc} CH = & CH\\ | & |\\ OH & OH\end{array}\right] \xrightarrow{H_2O + O} \underset{(\textit{Unstable})}{\left[\begin{array}{cc} OH & OH\\ | & |\\ CH - & CH\\ | & |\\ OH & OH\end{array}\right]} \xrightarrow{-2H_2O} \underset{\substack{\text{Glyoxal}\\ (\textit{Colourless})}}{\begin{array}{c} CH=O\\ |\\ CH=O\end{array}}$$

(*b*) Acetylene being *a terminal alkyne* gives a white ppt. of silver acetylide with ammoniacal silver nitrate solution (*Tollens' reagent*) and a red ppt. of copper acetylide with an ammoniacal solution of cuprous chloride while methane does not give these reactions.

$$\underset{\text{Acetylene}}{HC\equiv CH} + \underset{\text{Tollens' reagent}}{2[Ag(NH_3)_2]^+OH^-} \longrightarrow \underset{\substack{\text{Silver acetylide}\\ (\textit{White ppt.})}}{Ag-C\equiv C-Ag} + 4NH_3 + 2H_2O$$

$$\underset{\text{Acetylene}}{HC\equiv CH} + 2[Cu(NH_3)_2]^+\,OH^- \longrightarrow \underset{\substack{\text{Copper acetylide}\\ (\textit{Red ppt.})}}{Cu-C\equiv C-Cu} + 4NH_3 + 2H_2O$$

2. Ethylene and acetylene *(M.L.N.R. Allahabad 1995)*

Both ethylene and acetylene being *unsaturated hydrocarbons* decolourise Br_2 in CCl_4 solution and a cold dilute alkaline solution of $KMnO_4$ (*Baeyer's reagent*). These can, however, be distinguished by the following tests.

(a) **Cold conc. H_2SO_4 test.** When ethylene is passed through cold conc. H_2SO_4, it dissolves due to the formation of ethyl hydrogen sulphate but acetylene does not dissolve.

$$\underset{\text{Ethylene}}{CH_2 = CH_2} + H_2SO_4 \longrightarrow \underset{\text{Ethyl hydrogen sulphate}}{CH_3 - CH_2 - OSO_3H}$$

$$\underset{\text{Acetylene}}{CH \equiv CH} \xrightarrow{\text{Cold conc. } H_2SO_4} \text{No action}$$

(b) **Ammoniacal silver nitrate test.** With ammoniacal silver nitrate solution (*Tollens' reagent*), acetylene gives a white ppt. of silver acetylide but ethylene does not.

$$\underset{\text{Acetylene}}{HC \equiv CH} + \underset{\text{Tollens' reagent}}{2\,[Ag(NH_3)_2]^+\,OH^-} \longrightarrow \underset{\substack{\text{Silver acetylide}\\ (\textit{White ppt.})}}{Ag{-}C \equiv C{-}Ag} + 4NH_3 + 2H_2O$$

$$\underset{\text{Ethylene}}{CH_2 = CH_2} \xrightarrow{\text{Tollens' reagent}} \text{No action}$$

(c) **Ammoniacal cuprous chloride test.** With an ammoniacal solution of cuprous chloride, acetylene gives a red ppt. of copper acetylide while ethylene does not.

$$\underset{\text{Acetylene}}{HC \equiv CH} + 2[Cu(NH_3)_2]^+\,OH^- \longrightarrow \underset{\substack{\text{Copper acetylide}\\ (\textit{Red ppt.})}}{Cu{-}C \equiv C{-}Cu} + 4NH_3 + 2H_2O$$

$$\underset{\text{Ethylene}}{CH_2 = CH_2} \xrightarrow{\text{Ammoniacal cuprous chloride solution}} \text{No action}$$

3. 1-Butyne and 2-butyne *(I.I.T. 1985)*

Both 1-butyne and 2-butyne are alkynes. Whereas 1-butyne is a *terminal alkyne*, 2-butyne is a *non-terminal alkyne*. These can be distinguished by the following two tests :

(*a*) With ammoniacal silver nitrate solution (*Tollens' reagent*), 1-butyne gives a white ppt. of silver 1-butynide while 2-butyne does not react.

$$\underset{\substack{\text{1–Butyne}\\ (\textit{Terminal alkyne})}}{CH_3CH_2C \equiv CH} + \underset{\text{Tollens' reagent}}{[Ag(NH_3)_2]^+\,OH^-} \longrightarrow \underset{\substack{\text{Silver 1–butynide}\\ (\textit{White ppt.})}}{CH_3CH_2C \equiv CAg} + H_2O + 2NH_3$$

$$\underset{\substack{\text{2–Butyne}\\ (\textit{Non–terminal alkyne})}}{CH_3{-}C \equiv C{-}CH_3} + \underset{\text{Tollens' reagent}}{[Ag(NH_3)_2]^+\,OH^-} \longrightarrow \text{No reaction}$$

(*b*) Similarly, with ammoniacal cuprous chloride solution, 1- butyne gives a red ppt. of copper 1-butynide while 2-butyne does not react.

$$\underset{\text{1–Butyne}}{CH_3CH_2C \equiv CH} + [Cu(NH_3)_2]^+\,OH^- \longrightarrow \underset{\substack{\text{Copper 1–butynide}\\ (\textit{Red. ppt.})}}{CH_3CH_2C \equiv C{-}Cu} + H_2O + 2NH_3$$

$$\underset{\text{2–Butyne}}{CH_3{-}C \equiv C{-}CH_3} + [Cu(NH_3)_2]^+\,OH^- \longrightarrow \text{No reaction.}$$

4. Syrene and phenylacetylene

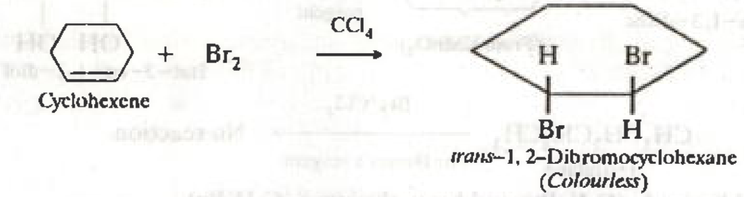
Phenylacetylene being a terminal alkyne will give white ppt. with ammoniacal $AgNO_3$ solution, (*Tollens' reagent*) but styrene being an alkene will not

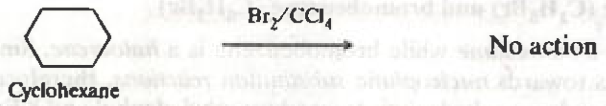
$$\underset{\text{Phenylacetylene}}{C_6H_5C \equiv CH} + \underset{\text{Tollens' reagent}}{[Ag(NH_3)_2]^+OH^-} \longrightarrow \underset{\substack{\text{Silver phenylacetylide} \\ (\textit{White ppt.})}}{C_6H_5C \equiv CAg} + 2\,NH_3 + H_2O$$

$$C_6H_5CH = CH_2 \xrightarrow{\text{Tollens' reagent}} \text{No action}$$

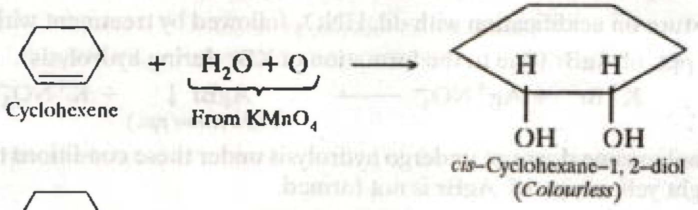
5. Cyclohexane and cyclohexene *(I.I.T. 1988)*

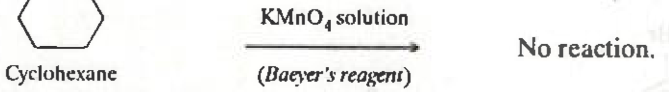
Cyclohexene is an alkene, *i.e.*, it contains a double bond. Therefore, it decolourises the orange colour of Br_2 in CCl_4 solution by forming the addition product. In contrast, cyclohexane is a saturated compound. As such it does not give this test since it does not contain a double bond.





A cold dilute alkaline solution of $KMnO_4$ (*Baeyer's reagent*) can also be used to distinguish between these two compounds. Add a few drops of Baeyer's reagent to each compound and shake. Cyclohexene decolourises the pink colour of $KMnO_4$ solution, whereas cyclohexane does not.





6. Buta-1, 3-diene and but-1-yne

But-1-yne is a *terminal alkyne* while buta-1, 3-diene is a conjugated diene. These can be distinguished by the following tests :

(*i*) With ammoniacal silver nitrate solution (*Tollens' reagent*), but-1-yne gives a white ppt. of silver but-1-ynide while buta-1,3-diene does not

$$\underset{\substack{\text{But}-1-\text{yne} \\ (\textit{Terminal alkyne})}}{CH_3CH_2C \equiv CH} + \underset{\text{Tollens' reagent}}{[Ag\,(NH_3)_2]^+\,OH^-} \longrightarrow \underset{\substack{\text{Silver but}-1-\text{ynide} \\ (\textit{white ppt.})}}{CH_3CH_2C \equiv CAg} + H_2O + 2\,NH_3$$

$$\underset{\text{Buta}-1,\,3-\text{diene}}{CH_2{=}CH{-}CH{=}CH_2} + \underset{\text{Tollens' reagent}}{[Ag\,(NH_3)_2]^+\,OH^-} \longrightarrow \text{No reaction}$$

(*ii*) Similarly, with ammoniacal cuprous chloride solution, but-1-yne gives red ppt. of copper but-1-ynide while buta-1,3-diene does not.

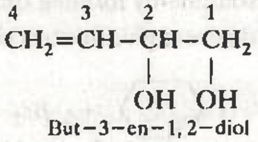
$$\underset{\text{But}-1-\text{yne}}{CH_3CH_2C \equiv CH} + [Cu\,(NH_3)_2]^+]\,OH^- \longrightarrow \underset{\substack{\text{Copper but}-1-\text{ynide} \\ (\textit{Red ppt.})}}{CH_3CH_2C \equiv CCu} + H_2O + 2\,NH_3$$

$$\underset{\text{Buta}-1,\,3-\text{diene}}{CH_2{=}CH{-}CH{=}CH_2} + [Cu(NH_3)_2]^+\,OH^- \longrightarrow \text{No reaction}$$

7. Buta-1, 3-diene and butane

Buta-1, 3-diene being an unsaturated hydrocarbon decolourizes Br_2/CCl_4 as well as cold dilute alkaline $KMnO_4$ solution (*Baeyer's reagent*) while butane being a saturated hydrocarbon does not respond to these tests.

$$\underset{\text{Buta-1, 3-diene}}{CH_2{=}CH{-}CH{=}CH_2} + Br_2 \xrightarrow[\text{1, 4-Addition}]{CCl_4} \underset{\text{1, 4-Dibromobut-2-ene}}{Br{-}CH_2{-}CH{=}CH{-}CH_2{-}Br}$$



$$\underset{\text{Buta-1, 3-diene}}{CH_2{=}CH{-}CH{=}CH_2} + \underbrace{H_2O + O}_{\text{(From } KMnO_4)} \xrightarrow[\text{reagent}]{\text{Baeyer's}} \underset{\text{But-3-en-1, 2-diol}}{\overset{4}{C}H_2{=}\overset{3}{C}H{-}\underset{OH}{\overset{2}{C}H}{-}\underset{OH}{\overset{1}{C}H_2}}$$

$$\underset{n\text{-Butane}}{CH_3CH_2CH_2CH_3} \xrightarrow[\text{or Baeyer's reagent}]{Br_2/CCl_4} \text{No reaction}$$

8. Ethyl bromide (C_2H_5Br) and bromobenzene (C_6H_5Br) *(A.I.S.B. 1991 S)*

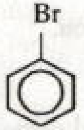
Ethyl bromide is a *haloalkane* while bromobenzene is a *haloarene*. Since haloalkanes are more reactive than haloarenes towards *nucleophilic substitution reactions*, therefore, when ethyl bromide is heated with *aq*. KOH, it undergoes hydrolysis to produce ethyl alcohol and KBr.

$$\underset{\text{Ethyl bromide}}{C_2H_5Br} + KOH\ (aq) \xrightarrow{\Delta} \underset{\text{Ethyl alcohol}}{C_2H_5OH} + K^+Br^-$$

The reaction mixture on acidification with dil. HNO_3 followed by treatment with $AgNO_3$ solution produces a light yellow ppt. of AgBr (due to the formation of KBr during hydrolysis).

$$K^+Br^- + Ag^+NO_3^- \longrightarrow \underset{\text{(Light yellow ppt.)}}{AgBr\downarrow} + K^+NO_3^-$$

In contrast, bromobenzene does not undergo hydrolysis under these conditions to produce phenol and KBr. Therefore, light yellow ppt. of AgBr is not formed.



$$+ KOH\ (aq) \xrightarrow{\Delta} \text{No reaction}$$

Bromobenzene

9. Chlorobenzene (C_6H_5Cl) and n-hexyl chloride ($C_6H_{13}Cl$)

(A.I.S.B. 1988 ; P.S.B. 1989)

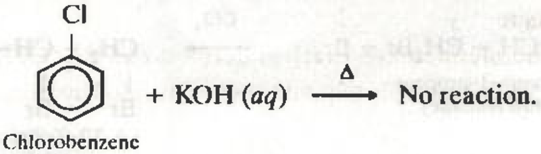
n-Hexyl chloride is a *haloalkane* while chlorobenzene is a *haloarene*. Since haloalkanes are more reactive than haloarenes towards *nucleophilic substitution reactions*, therefore, when *n*- hexyl chloride is heated with *aq*. KOH, it undergoes hydrolysis to produce *n*-hexyl alcohol and KCl.

$$\underset{n\text{-Hexyl chloride}}{CH_3(CH_2)_4CH_2{-}Cl} + KOH\ (aq) \xrightarrow{\Delta} \underset{n\text{-Hexyl alcohol}}{CH_3(CH_2)_4CH_2{-}OH} + K^+Cl^-$$

$$K^+Cl^- + Ag^+\,NO_3^- \longrightarrow \underset{\text{(White ppt.)}}{AgCl\downarrow} + K^+NO_3^-$$

The reaction mixture on acidification with dil. HNO_3 followed by treatment with $AgNO_3$ solution produces a white ppt. of AgCl due to the formation of KCl during the hydrolysis reaction.

In contrast, chlorobenzene does not undergo hydrolysis under these conditions to produce phenol and KCl.



Therefore, treatment of the reaction mixture with dil. HNO_3 followed by addition of $AgNO_3$ does not produce a white ppt. of AgCl.

10. Chlorobenzene (C_6H_5Cl) and benzyl chloride ($C_6H_5CH_2Cl$)

(P.S.B. 1989 ; H.S.B. 1992 ; D.S.B. 1995 ; C.B.S.E. Sample Paper 1997 ; N.C.E.R.T.)

Benzyl chloride is an *aralkyl halide* while chlorobenzene is an *aryl halide*. Since aralkyl halides are even more reactive than alkyl halides towards *nucleophilic substitution reactions*, therefore, benzyl chloride on boiling with aq. KOH produces benzyl alcohol and KCl.

$$\underset{\text{Benzyl chloride}}{C_6H_5CH_2Cl} + KOH\,(aq) \xrightarrow{\text{Boil}} \underset{\text{Benzyl alcohol}}{C_6H_5CH_2OH} + K^+Cl^-$$

The reaction mixture on acidification with dil. HNO_3 followed by treatment with $AgNO_3$ solution produces white ppt. of AgCl due to the formation of KCl.

$$K^+Cl^- + Ag^+NO_3^- \longrightarrow \underset{\textit{(White ppt.)}}{AgCl\downarrow} + K^+NO_3^-$$

In contrast, chlorobenzene does not undergo hydrolysis under these mild conditions to give phenol and KCl.

$$\underset{\text{Chlorobenzene}}{C_6H_5Cl} + KOH\,(aq) \xrightarrow{\text{Boil}} \text{No reaction}$$

Therefore, acidification of the reaction mixture with dil. HNO_3 followed by addition of $AgNO_3$ solution does not produce a white ppt. of AgCl.

11. Bromobenzene (C_6H_5Br) and benzyl bromide ($C_6H_5CH_2Br$) *(P.S.B. 1995)*

Benzyl bromide is an *aralkyl halide* while bromobenzene is an *aryl halide*. Since arakyl halides are more reactive than even alkyl halides towards *nucleophilic substitution reactions*, therefore, benzyl bromide on boiling with an aqueous solution of KOH will undergo hydrolysis to produce benzyl alcohol and KBr.

$$\underset{\text{Benzyl bromide}}{C_6H_5CH_2Br} + KOH\,(aq) \xrightarrow{\text{Boil}} \underset{\text{Benzyl alcohol}}{C_6H_5CH_2OH} + K^+Br^-$$

The reaction mixture on acidification with dil. HNO_3 followed by addition of $AgNO_3$ solution produces light yellow ppt. of AgBr due to the formation of KBr.

$$K^+\,Br^- + Ag^+\,NO_3^- \longrightarrow \underset{\textit{(Light yellow ppt.)}}{AgBr\downarrow} + K^+NO_3^-$$

In contrast, bromobenzene being much less reactive than benzyl bromide does not undergo hydrolysis under these mild conditions to give phenol and KBr.

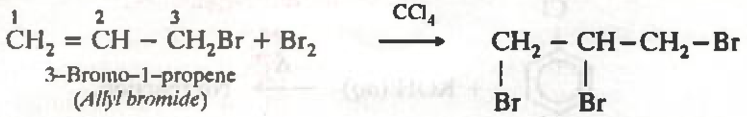
$$\underset{\text{Bromobenzene}}{C_6H_5Br} + KOH\,(aq) \xrightarrow{\text{Boil}} \text{No reaction}$$

Therefore, acidification of the reaction mixture with dil. HNO_3 followed by addition of $AgNO_3$ solution does not produce a light yellow ppt. of AgBr.

12. 3-Bromo-1-propene ($CH_2{=}CH{-}CH_2Br$) and 1-bromopropane ($CH_3CH_2CH_2Br$)

(D.S.B. 1985)

3-Bromo-1-propene contains a double bond and thus decolourises the orange colour of Br_2 in CCl_4 solution by forming the addition product.



$$\overset{1}{CH_2} = \overset{2}{CH} - \overset{3}{CH_2}Br + Br_2 \xrightarrow{CCl_4} \underset{Br}{CH_2} - \underset{Br}{CH} - CH_2 - Br$$

3-Bromo-1-propene (*Allyl bromide*) 1, 2,3-Tribromopropane (*Colourless*)

In contrast, 1-bromopropane does not give this test since it does not contain a double bond.

$$\underset{\text{1-Bromopropane}}{CH_3CH_2CH_2Br} + Br_2 \xrightarrow{CCl_4} \text{No reaction.}$$

A cold dilute alkaline solution of $KMnO_4$ (*Baeyer's reagent*) can also be used to distinguish between these compounds. Add a few drops of Baeyer's reagent to each compound and shake. Whereas 3-bromo-1-propene decolourises the pink colour of *Baeyer's reagent*, 1-bromopropane does not.

$$\underset{\text{3-Bromo-1-propene}}{CH_2{=}CH{-}CH_2Br} + \underbrace{H_2O + O}_{\text{From } KMnO_4} \longrightarrow \underset{\substack{\text{3-Bromopropane-1, 2-diol} \\ (\textit{Colourless})}}{HOCH_2{-}CHOH{-}CH_2Br}$$

$$\underset{\text{1-Bromopropane}}{CH_3CH_2CH_2{-}Br} \xrightarrow{KMnO_4\text{ solution}} \text{No reaction.}$$

13. p-Chlorotoluene (p-$ClC_6H_4CH_3$) and benzyl chloride ($C_6H_5CH_2Cl$)

These may be distinguished by the following tests : –

(*i*) $AgNO_3$ test. Benzyl chloride on boiling with aq. KOH solution undergoes hydrolysis to give benzyl alcohol and KCl.

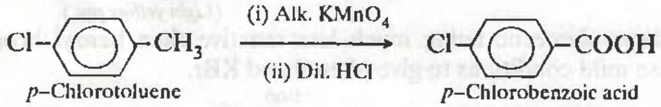
$$\underset{\text{Benzyl chloride}}{C_6H_5CH_2Cl} + KOH\ (aq) \xrightarrow{\Delta} \underset{\text{Benzyl alcohol}}{C_6H_5CH_2OH} + K^+Cl^-$$

The reaction mixture on acidification with dil. HNO_3 followed by treatment with $AgNO_3$ solution produces white ppt. of AgCl (due to the formation of KCl during hydrolysis).

$$K^+Cl^- + AgNO_3 \longrightarrow \underset{(\textit{White ppt.})}{AgCl\downarrow} + K^+NO_3^-$$

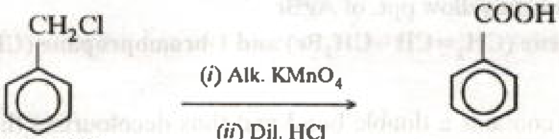
In contrast, *p*-chlorotoluene does not undergo hydrolysis under these conditions to produce *p*-cresol and KCl. Therefore, it does not give white ppt. of AgCl.

(*ii*) **Oxidation test.** *p*-Chlorotoluene on oxidation with alkaline $KMnO_4$ solution followed by acidification gives *p*-chlorobenzoic acid which gives green edged flame during *Beilstein test* due to the presence of Cl in it.



p-Chlorotoluene *p*-Chlorobenzoic acid (m.p. 512–514 K)

In contast, benzyl chloride on oxidation with alkaline $KMnO_4$ followed by acidification gives benzoic acid which does not give *Beilstein test* due to the absence of Cl.



Benzyl chloride Benzoic acid (m.p. 394 K)

14. Chloroform ($CHCl_3$) and carbon tetrachloride (CCl_4)

(D.S.B. 1988 ; P.S.B. 2003)

These two compounds can be distinguished by the *Carbylamine test* as given below :

Carbylamine test. Chloroform on warming with an alcoholic solution of aniline and KOH gives carbylamine having offensive smell while carbon tetrachloride does not give this test.

$$\underset{\text{Chloroform}}{CHCl_3} + \underset{\text{Aniline}}{C_6H_5NH_2} + \underset{(alc.)}{3KOH} \xrightarrow{\text{warm}} \underset{\substack{\text{Phenyl isocyanide} \\ (\textit{Offensive smelling compound})}}{C_6H_5N \rightleftarrows C} + 3KCl + 3H_2O$$

$$CCl_4 + C_6H_5NH_2 + KOH \xrightarrow{\text{warm}} \text{No reaction}$$

15. n-Butylamine and diethylamine

(N.C.E.R.T)

1° Amines give *carbylamine reaction* while 2° and 3° amines do not. Therefore, *n*-butylamine being a 1° amine, on heating with chloroform and alcoholic solution of KOH, will give offensive smell of carbylamine while diethylamine being a 2° amine does not.

$$\underset{\substack{n-\text{Butylamine} \\ (1°\,\textit{Amine})}}{CH_3CH_2CH_2CH_2NH_2} + CHCl_3 + 3\,KOH\,(alc.) \xrightarrow{\Delta} \underset{\substack{n-\text{Butyl carbylamine} \\ (\textit{Offensive small})}}{CH_3CH_2CH_2CH_2N \rightleftarrows C} + 3\,KCl + 3\,H_2O$$

$$\underset{\substack{\text{Diethylamine} \\ (2°\text{ Amine})}}{(CH_3CH_2)_2NH} \xrightarrow{CHCl_3,\ KOH\,(alc.),\ \Delta} \text{No reaction}$$

16. Methanol (CH_3OH) and ethanol (CH_3CH_2OH)

(I.I.T. 1985 ; A.I.S.B. 1986, 95 ; D.S.B. 1988, 89 S ; 2001, H.P.S.B. 1988 ; C.B.S.E Sample Paper, 1997 ; P.S.B. 1989 S, 91 S, 2001 ; N.C.E.R.T.)

These can be distinguished by the *iodoform test* as given below :

Iodoform test. Ethanol contains the grouping $-CHOHCH_3$ and hence when warmed with sodium hypoiodite (NaOI), *i.e.*, I_2 in NaOH, it gives yellow ppt. of iodoform.

$$\underset{\text{Ethanol}}{CH_3CH_2OH} + NaOI \longrightarrow \underset{\text{Acetaldehyde}}{CH_3CHO} + NaI + H_2O$$

$$\underset{\text{Acetaldehyde}}{CH_3CHO} + 3NaOI \longrightarrow \underset{\text{Iodoform}}{CHI_3 \downarrow} + \underset{\text{Sod. formate}}{HCOONa} + 2NaOH$$

On the other hand, methanol (CH_3OH) does not contain the grouping $-CHOHCH_3$ and hence it does not give the iodoform test.

$$\underset{\text{Methanol}}{CH_3OH} \xrightarrow{NaOI} \text{No yellow ppt. of } CHI_3$$

17. Ethanol (CH_3CH_2OH) and 1-propanol ($CH_3CH_2CH_2OH$)

(D.S.B. 1995)

These can be distinguished by the *iodoform test* as given below :

Iodoform test. Ethanol contains the grouping $CH_3CHOH -$ and hence when warmed with sodium hypoiodite (NaOI), *i.e.*, I_2 in NaOH, it gives yellow ppt. of iodoform (CHI_3).

$$\underset{\text{Ethanol}}{CH_3CH_2OH} + NaOI \longrightarrow \underset{\text{Ethanal}}{CH_3CHO} + NaI + H_2O$$

$$\underset{\text{Ethanal}}{CH_3CHO} + 3NaOI \longrightarrow \underset{\text{Iodoform}}{CHI_3 \downarrow} + \underset{\text{Sod. formate}}{HCOONa} + 2NaOH$$

On the other hand, 1-propanol ($CH_3CH_2CH_2OH$) does not contain the grouping CH_3CHOH- and hence it does not give iodoform test on treatment with NaOI.

$$\underset{\text{1-Propanol}}{CH_3CH_2CH_2OH} \xrightarrow{\text{NaOI}} \text{No yellow ppt. of } CHI_3$$

18. 1-Propanol ($CH_3CH_2CH_2OH$) and 2-propanol ($CH_3CHOHCH_3$)

(A.I.S.B. 1989 ; D.S.B. 1988 ; P.S.B. 1989 S, 2001 ; H.P.S.B. 1988, 92 ; Maharashtra 2001 ; N.C.E.R.T.)

These can be distinguished by the *iodoform test* as given below :

Iodoform test. 2-Propanol ($CH_3CHOHCH_3$) contains the grouping $-CHOHCH_3$ and hence when warmed with sodium hypoiodite (NaOI), *i.e.*, I_2 in NaOH, it gives yellow ppt. of iodoform. In contrast, 1-propanol does not contain the grouping $-CHOHCH_3$ and hence does not respond to iodoform test.

$$\underset{\text{2-Propanol}}{CH_3-CHOHCH_3} + NaOI \longrightarrow \underset{\text{Acetone}}{CH_3-COCH_3} + NaI + H_2O$$

$$\underset{\text{Acetone}}{CH_3-COCH_3} + 3NaOI \longrightarrow \underset{\substack{\text{Iodoform}\\(\textit{Yellow ppt.})}}{CHI_3\downarrow} + \underset{\text{Sod. acetate}}{CH_3COONa} + 2NaOH$$

$$\underset{\text{1-Propanol}}{CH_3CH_3CH_2OH} \xrightarrow{\text{NaOI}} \text{No yellow ppt. of } CHI_3$$

19. Propanol ($CH_3CH_2CH_2OH$) and propanone (CH_3COCH_3) *(D.S.B. 1998)*

As discussed above these can be distinguished by the *iodoform test.*

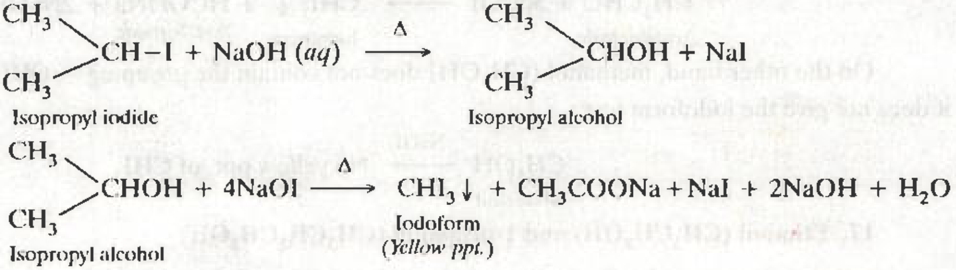
Iodoform test. Propanone (CH_3COCH_3) contains the grouping $-COCH_3$ and hence when warmed with sodium hypoiodite (NaOI), *i.e.*, I_2/NaOH, it gives yellow ppt. of iodoform. In contrast, propanol does not contain the grouping $-COCH_3$ and hence does not resond to iodoform test.

For reactions, refer to distinction 18 between 1-propanol and 2-propanol.

20. n-Propyl iodide ($CH_3CH_2CH_2I$) and isopropyl iodide (CH_3CHICH_3)

These two compounds may be distinguished as follows :

Iodoform test. Isopropyl iodide on alkaline hydrolysis gives isopropyl alcohol (2-*propanol*) which upon subsequent treatment with NaOI (I_2/NaOH) gives yellow ppt. of iodoform.



$$\underset{\text{Isopropyl iodide}}{(CH_3)_2CH-I} + NaOH\,(aq) \xrightarrow{\Delta} \underset{\text{Isopropyl alcohol}}{(CH_3)_2CHOH} + NaI$$

$$\underset{\text{Isopropyl alcohol}}{(CH_3)_2CHOH} + 4NaOI \xrightarrow{\Delta} \underset{\substack{\text{Iodoform}\\(\textit{Yellow ppt.})}}{CHI_3\downarrow} + CH_3COONa + NaI + 2NaOH + H_2O$$

In contrast, *n*-propyl iodide on alkaline hydrolysis gives *n*-propyl alcohol (1-*propanol*) which on subsequent treatment with NaOI (I_2/NaOH) does not give yellow ppt. of CHI_3 (*iodoform test*).

$$\underset{n\text{-Propyl iodide}}{CH_3CH_2CH_2I} + NaOH\,(aq) \longrightarrow \underset{n\text{-Propyl alcohol}}{CH_2CH_2CH_2OH} + NaI$$

$$\downarrow \text{NaOI}$$

$$\text{No yellow ppt. of } CHI_3$$

APPENDIX

3

Some Typical Conversion

1. Methane into ethane

$$\underset{\text{Methane}}{CH_4} \xrightarrow[\text{Sunlight}]{Cl_2} \underset{\text{Methyl chloride}}{CH_3Cl} \xrightarrow[\textit{(Wurtz reaction)}]{\text{Na, Dry ether}} \underset{\text{Ethane}}{CH_3-CH_3}$$

2. Ethane to butane

$$\underset{\text{Ethane}}{CH_3CH_3} \xrightarrow[\text{Sunlight}]{Cl_2} \underset{\text{Ethyl chloride}}{CH_3CH_2Cl} \xrightarrow[\textit{(Wurtz reaction)}]{\text{Na, Dry ether}} \underset{\text{Butane}}{CH_3CH_2-CH_2CH_3}$$

(N.C.E.R.T.)

3. 1-Chlorobutane to n-octane

$$\underset{\text{1−Chlorobutane}}{CH_3CH_2CH_2CH_2-Cl} \xrightarrow[(-\,2\ NaCl),\ \text{Wurtz reaction}]{\text{2 Na, dry ether}} \underset{n-\text{Octane}}{CH_3(CH_2)_6CH_3}$$

4. Ethane to propane

$$\underset{\text{Ethane}}{CH_3CH_3} \xrightarrow[\text{sunlight}]{Cl_2} \underset{\text{Ethyl chloride}}{CH_3CH_2Cl} \xrightarrow[\text{dry ether}]{Li} \underset{\text{Ethyl lithium}}{CH_3CH_2Li} \xrightarrow{CuI} (CH_3CH_2)_2CuLi$$

$$\xrightarrow{CH_3-I} \underset{\text{Propane}}{CH_3CH_2CH_3} + CH_3CH_2Cu + LiI$$

5. Propane to ethane

$$\underset{\text{Propane}}{CH_3CH_2CH_3} \xrightarrow[\text{Sunlight}]{Cl_2} [\underset{\text{1−Chloropropane}}{CH_3CH_2CH_2Cl} + \underset{\text{2−Chloropropane}}{CH_3-CHCl-CH_3}] \xrightarrow[\textit{(Dehydrohalogenation)}]{\text{KOH alc.}, \Delta}$$

$$\underset{\text{Propene}}{CH_3CH=CH_2} \xrightarrow[\textit{(Anti−Mark. addn.)}]{\text{HBr, peroxide}} \underset{\text{1−Bromopropane}}{CH_3CH_2CH_2Br} \xrightarrow{\text{KOH aq.}, \Delta}$$

$$\underset{\text{Propan−1−ol}}{CH_3CH_2CH_2OH} \xrightarrow[\textit{(oxidation)}]{K_2Cr_2O_7/H_2SO_4} \underset{\text{Propanal}}{[CH_3CH_2CHO]} \xrightarrow{[O]}$$

$$\underset{\text{Propanoic acid}}{CH_3CH_2COOH} \xrightarrow{NaOH} \underset{\text{Sod. propanoate}}{CH_3CH_2COONa} \xrightarrow[\textit{(Decarboxylation)}]{\text{NaOH + CaO, 633 K}} \underset{\text{Ethane}}{CH_3-CH_3}$$

6. Ethane to ethylene

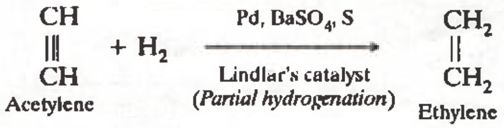
$$\underset{\text{Ethane}}{CH_3CH_3} \xrightarrow[\text{Sunlight}]{Cl_2} \underset{\text{Ethyl chloride}}{CH_3CH_2Cl} \xrightarrow[\textit{(Dehydrochlorination)}]{\text{KOH alc.}\ \Delta} \underset{\text{Ethylene}}{CH_2=CH_2}$$

7. n-Propyl chloride to propylene

$$\underset{n\text{-Propyl chloride}}{CH_3CH_2CH_2Cl} + KOH\ (alc.) \xrightarrow[\text{(Dehydrochlorination)}]{\Delta} \underset{\text{Propylene}}{CH_3CH{=}CH_2} + KCl + H_2O$$

8. Acetylene to ethylene

(A.I.S.B. 1986)



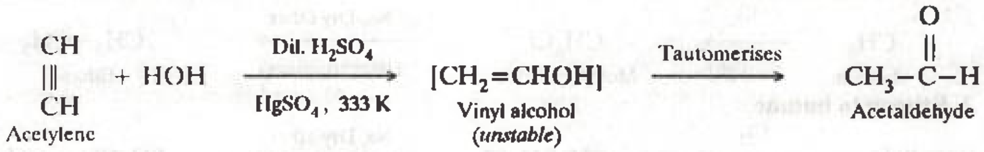
$$\underset{\text{Acetylene}}{\begin{array}{c}CH\\|||\\CH\end{array}} + H_2 \xrightarrow[\substack{\text{Lindlar's catalyst}\\ \text{(Partial hydrogenation)}}]{\text{Pd, BaSO}_4\text{, S}} \underset{\text{Ethylene}}{\begin{array}{c}CH_2\\||\\CH_2\end{array}}$$

9. Propene to propane

$$\underset{\text{Propene}}{CH_3CH{=}CH_2} + H_2 \xrightarrow[\text{(Hydrogenation)}]{\text{Ni, 523-573 K}} \underset{\text{Propane}}{CH_3-CH_2-CH_3}$$

10. Acetylene to acetaldehyde

(H.S.B. 1986, P.S.B. 1987)



$$\underset{\text{Acetylene}}{\begin{array}{c}CH\\|||\\CH\end{array}} + HOH \xrightarrow[\text{HgSO}_4\text{, 333 K}]{\text{Dil. H}_2\text{SO}_4} \underset{\substack{\text{Vinyl alcohol}\\ \text{(unstable)}}}{[CH_2{=}CHOH]} \xrightarrow{\text{Tautomerises}} \underset{\text{Acetaldehyde}}{CH_3-\overset{\overset{\displaystyle O}{||}}{C}-H}$$

11. Ethyne to methane

$$\underset{\text{Ethyne}}{CH{\equiv}CH} \xrightarrow[\text{333 K}]{\text{Dil. H}_2\text{SO}_4\text{, HgSO}_4} \underset{\text{Ethanal}}{CH_3-CHO} \xrightarrow[\text{(Oxidation)}]{K_2Cr_2O_7/H_2SO_4} \underset{\text{Ethanoic acid}}{CH_3COOH}$$

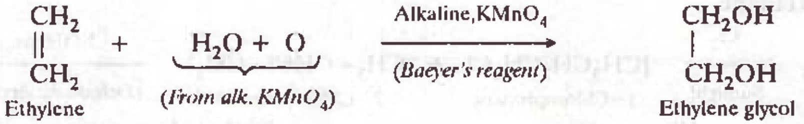
$$\xrightarrow{\text{NaOH}} \underset{\text{Sod. acetate}}{CH_3COONa} \xrightarrow[\text{(Decarboxylation)}]{\text{NaOH + CaO, 633 K}} \underset{\text{Methane}}{CH_4}$$

12. Acetylene to glyoxal

$$\underset{\text{Acetylene}}{HC \equiv CH} \xrightarrow[\text{(ii) Zn/H}_2\text{O}]{\text{(i) O}_3\text{/CH}_2\text{Cl}_2} \underset{\text{Glyoxal}}{O = HC-CH = O}$$

13. Ethylene to ethylene glycol

(H.S.B. 1988, H.P.S.B. 1987 D.S.B. 1996)

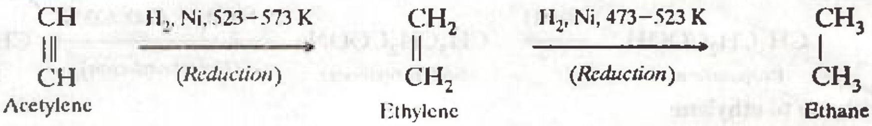


$$\underset{\text{Ethylene}}{\begin{array}{c}CH_2\\||\\CH_2\end{array}} + \underbrace{H_2O + O}_{\text{(From alk. KMnO}_4)} \xrightarrow[\text{(Baeyer's reagent)}]{\text{Alkaline, KMnO}_4} \underset{\text{Ethylene glycol}}{\begin{array}{c}CH_2OH\\|\\CH_2OH\end{array}}$$

14. Ethyl alcohol to ethylene

$$\underset{\text{Ethyl alcohol}}{CH_3-CH_2-OH} \xrightarrow[\text{(Dehydration)}]{\text{Conc. H}_2\text{SO}_4\text{, 440 K}} \underset{\text{Ethylene}}{CH_2{=}CH_2} + H_2O$$

15. Acetylene to ethane



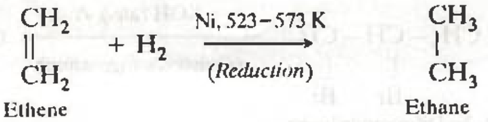
$$\underset{\text{Acetylene}}{\begin{array}{c}CH\\|||\\CH\end{array}} \xrightarrow[\text{(Reduction)}]{\text{H}_2\text{, Ni, 523-573 K}} \underset{\text{Ethylene}}{\begin{array}{c}CH_2\\||\\CH_2\end{array}} \xrightarrow[\text{(Reduction)}]{\text{H}_2\text{, Ni, 473-523 K}} \underset{\text{Ethane}}{\begin{array}{c}CH_3\\|\\CH_3\end{array}}$$

16. Ethyne to propyne

$$\underset{\text{Ethyne}}{CH \equiv CH} \xrightarrow[\text{liq. NH}_3\text{, 196 K}]{\text{NaNH}_2\text{ (1 equiv)}} \underset{\text{Sod. acetylide}}{CH \equiv C^- Na^+} \xrightarrow[-\text{NaBr}]{CH_3-Br} \underset{\text{Propyne}}{CH_3-C \equiv CH}$$

17. Ethene to ethane

(H.S.B. 1988)



$$\underset{\text{Ethene}}{CH_2{=}CH_2} + H_2 \xrightarrow[\textit{(Reduction)}]{\text{Ni, 523–573 K}} \underset{\text{Ethane}}{CH_3{-}CH_3}$$

18. Acetylene to but-1-yne

(P.S.B. 1987)

$$\underset{\text{Acetylene}}{CH \equiv CH} \xrightarrow[\text{196 K}]{\text{NaNH}_2\text{, liq. NH}_3} \underset{\text{Sod. acetylide}}{CH \equiv C\overset{-}{}\overset{+}{Na}} \xrightarrow[-\text{NaBr}]{CH_3CH_2Br} \underset{\text{But-1-yne}}{CH_3CH_2C \equiv CH}$$

19. Acetylene to pent-2-yne

(N.C.E.R.T.)

First convert acetylene to but-1-yne as shown in conversion 18 and then convert it into pent-2-yne as follows :

$$\underset{\text{But-1-yne}}{CH_3CH_2C \equiv CH} \xrightarrow[\text{liq. NH}_3]{\text{NaNH}_2\text{ in}} \underset{\text{Sod. but-1-ynide}}{CH_3CH_2C \equiv C^-Na^+} \xrightarrow[-\text{NaI}]{CH_3I} \underset{\text{Pent-2-yne}}{CH_3CH_2C \equiv CCH_3}$$

Alternatively

First convert acetylene to propyne as shown in conversion 16 and then convert into pent-2-yne as follows.

$$\underset{\text{Propyne}}{CH_3C \equiv CH} \xrightarrow[\text{196 K}]{\text{Na in liq. NH}_3} \underset{\text{Sod. Propynide}}{CH_3C \equiv C^-Na^+} \xrightarrow[-\text{NaBr}]{CH_3CH_2Br} \underset{\text{Pent-2-yne}}{CH_3-C \equiv C-CH_2CH_3}$$

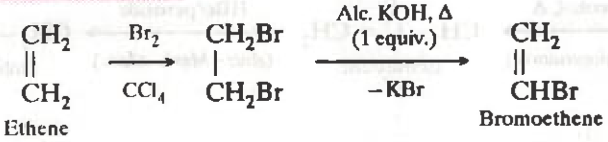
20. Ethanol to but-1-yne

(N.C.E.R.T.)

$$\underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow[\text{Reflux}]{\text{NaBr, H}_2\text{SO}_4} \underset{\text{Bromoethane}}{CH_3CH_2Br} \xrightarrow[\text{in liq. NH}_3]{HC \equiv C^-Na^+} \underset{\text{But-1-yne}}{CH_3CH_2C \equiv CH}$$

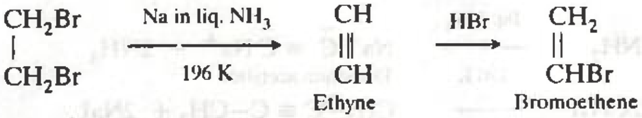
21. Ethene to bromoethene

(N.C.E.R.T.)



$$\underset{\text{Ethene}}{CH_2{=}CH_2} \xrightarrow[CCl_4]{Br_2} CH_2Br{-}CH_2Br \xrightarrow[-\text{KBr}]{\text{Alc. KOH, }\Delta\text{ (1 equiv.)}} \underset{\text{Bromoethene}}{CH_2{=}CHBr}$$

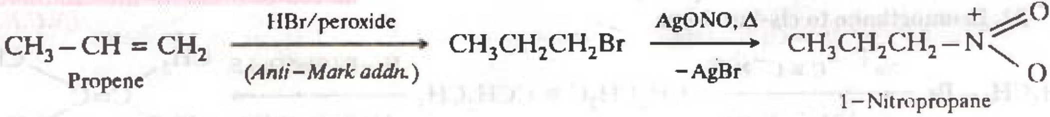
Alternatively



$$CH_2Br{-}CH_2Br \xrightarrow[\text{196 K}]{\text{Na in liq. NH}_3} \underset{\text{Ethyne}}{CH \equiv CH} \xrightarrow{HBr} \underset{\text{Bromoethene}}{CH_2{=}CHBr}$$

22. Propene to 1-nitropropane

(N.C.E.R.T.)



$$\underset{\text{Propene}}{CH_3-CH=CH_2} \xrightarrow[\textit{(Anti-Mark addn.)}]{\text{HBr/peroxide}} CH_3CH_2CH_2Br \xrightarrow[-\text{AgBr}]{\text{AgONO, }\Delta} \underset{\text{1-Nitropropane}}{CH_3CH_2CH_2-\overset{+}{N}(=O)O^-}$$

23. Propene to 1-iodopropane

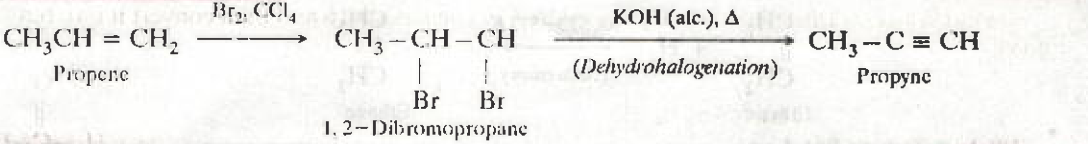
$$\underset{\text{Propene}}{CH_3CH=CH_2} \xrightarrow[\text{Anti-Mark addn.}]{\text{HBr/peroxide}} CH_3CH_2CH_2Br \xrightarrow[\textit{(Finkelstein reaction)}]{\text{KI/Acetone}} \underset{\text{1-Iodopropane}}{CH_3CH_2CH_2I}$$

24. Ethanol to ethyl fluoride

(N.C.E.R.T.)

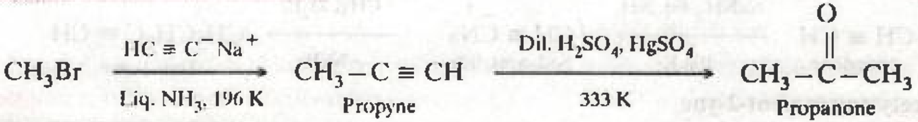
$$\underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow[\Delta]{\text{NaBr, H}_2\text{SO}_4} \underset{\text{Ethyl bromide}}{CH_3CH_2Br} \xrightarrow[\text{Swarts reaction}]{Hg_2F_2\,(-Hg_2Br_2)} \underset{\text{Ethyl fluoride}}{CH_3CH_2F}$$

25. Propene to propyne *(N.C.E.R.T.)*



$$\underset{\text{Propene}}{CH_3CH=CH_2} \xrightarrow{Br_2,\ CCl_4} \underset{\text{1, 2-Dibromopropane}}{CH_3-\underset{Br}{\underset{|}{CH}}-\underset{Br}{\underset{|}{CH}}} \xrightarrow[\textit{(Dehydrohalogenation)}]{\text{KOH (alc.)},\ \Delta} \underset{\text{Propyne}}{CH_3-C\equiv CH}$$

26. Bromoethane to propanone *(N.C.E.R.T.)*

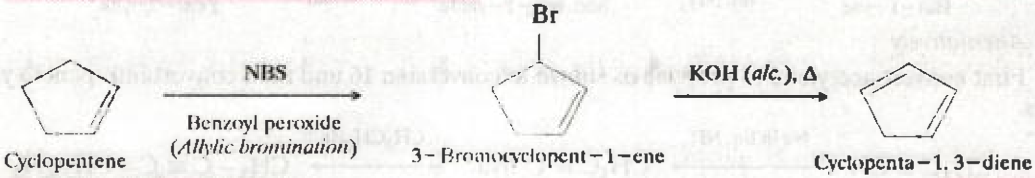


$$CH_3Br \xrightarrow[\text{Liq. } NH_3,\ 196\text{ K}]{HC\equiv C^-Na^+} \underset{\text{Propyne}}{CH_3-C\equiv CH} \xrightarrow[333\text{ K}]{\text{Dil. } H_2SO_4,\ HgSO_4} \underset{\text{Propanone}}{CH_3-\overset{\overset{O}{\|}}{C}-CH_3}$$

27. But-1-ene to but-2-ene *(N.C.E.R.T.)*

$$\underset{\text{But}-1-\text{ene}}{CH_3CH_2CH=CH_2} \xrightarrow[\textit{(Mark. addn.)}]{HBr} CH_3CH_2-CHBr-CH_3 \xrightarrow[\textit{(Saytzeff rule)}]{\text{KOH (alc.)},\ \Delta} \underset{\text{But}-2-\text{ene}}{CH_3CH=CHCH_3}$$

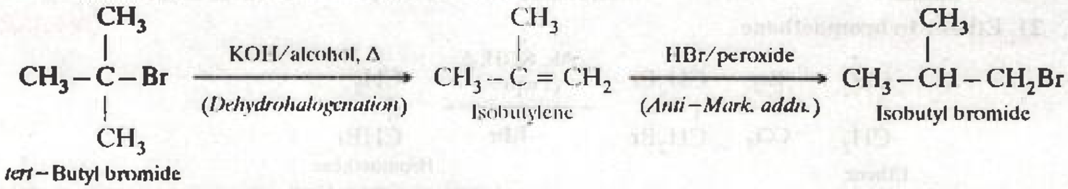
28. Cyclopentene to cyclopenta-1, 3-diene *(N.C.E.R.T.)*



29. Butan-1-ol to but-1-ene *(N.C.E.R.T.)*

$$\underset{\text{Butan}-1-\text{ol}}{CH_3CH_2CH_2CH_2OH} \xrightarrow[\Delta]{NaBr/H_2SO_4} \underset{1-\text{Bromobutane}}{CH_3CH_2CH_2CH_2Br} \xrightarrow[\textit{(Dehydrohalogenation)}]{\text{KOH/alcohol},\ \Delta} \underset{\text{But}-1-\text{ene}}{CH_3CH_2CH=CH_2}$$

30. tert-Butyl bromide to isobutyl bromide *(N.C.E.R.T.)*



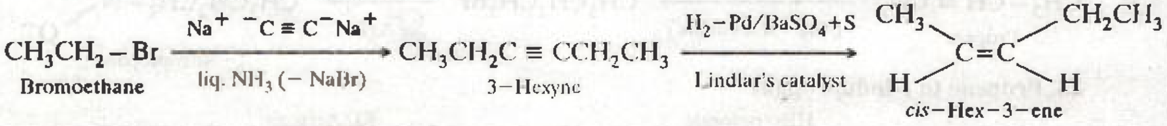
$$\underset{\textit{tert}-\text{Butyl bromide}}{CH_3-\underset{CH_3}{\underset{|}{\overset{CH_3}{\overset{|}{C}}}}-Br} \xrightarrow[\textit{(Dehydrohalogenation)}]{\text{KOH/alcohol},\ \Delta} \underset{\text{Isobutylene}}{CH_3-\overset{CH_3}{\overset{|}{C}}=CH_2} \xrightarrow[\textit{(Anti-Mark. addn.)}]{HBr/\text{peroxide}} \underset{\text{Isobutyl bromide}}{CH_3-\overset{CH_3}{\overset{|}{CH}}-CH_2Br}$$

31. Acetylene to but-2-yne or CH_3I to but-2-yne *(P.S.B. 1994)*

$$\underset{\text{Acetylene}}{CH\equiv CH} + 2NaNH_2 \xrightarrow[196\text{ K}]{\text{liq. } NH_3} \underset{\text{Disodium acetylide}}{Na^+\overset{-}{C}\equiv\overset{-}{C}Na^+} + 2NH_3$$

$$\underset{\text{Disodium acetylide}}{Na^+\overset{-}{C}\equiv\overset{-}{C}Na^+} + \underset{\textit{(excess)}}{2CH_3I} \longrightarrow \underset{\text{But-2-yne}}{CH_3-C\equiv C-CH_3} + 2NaI$$

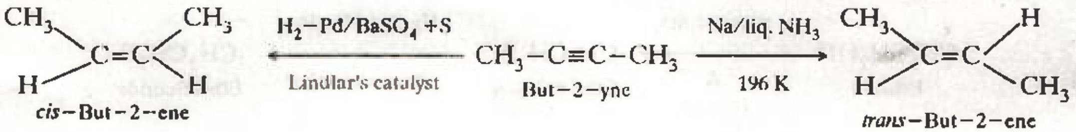
32. Bromoethane to cis-hex-3-ene *(N.C.E.R.T.)*



$$\underset{\text{Bromoethane}}{CH_3CH_2-Br} \xrightarrow[\text{liq. } NH_3\ (-\ NaBr)]{Na^+\ {}^-C\equiv C^-Na^+} \underset{3-\text{Hexyne}}{CH_3CH_2C\equiv CCH_2CH_3} \xrightarrow[\text{Lindlar's catalyst}]{H_2-Pd/BaSO_4+S}$$

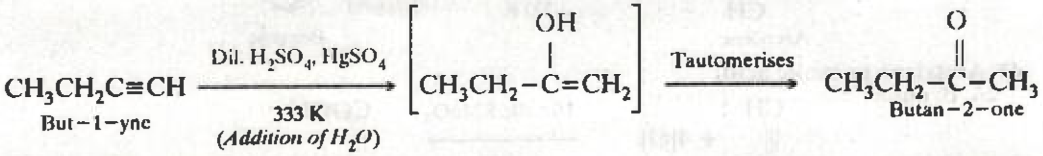
33. Ethyne to cis- and trans-but-2-ene

First convert acetylene (ethyne) to but-2-yne as shown in conversion 31 and then convert it into *cis*- and *trans*-but-2-enes as follows.



34. Ethyne into butan-2-one

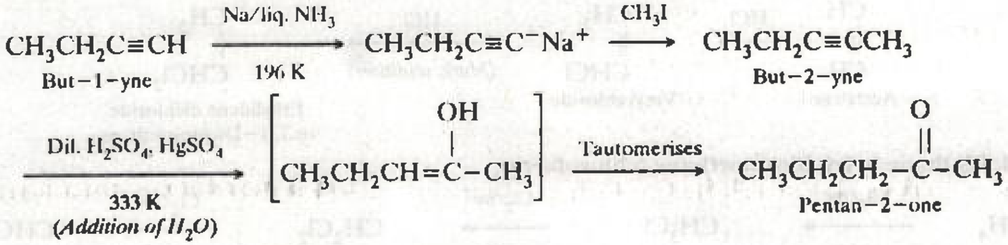
First convert ethyne into but-1-yne as shown in conversion **16** and then convert it into but-2-one as follows :



$$\underset{But-1-yne}{CH_3CH_2C\equiv CH} \xrightarrow[\substack{333\ K\\ (Addition\ of\ H_2O)}]{Dil.\ H_2SO_4,\ HgSO_4} \left[CH_3CH_2-\overset{OH}{\overset{|}{C}}=CH_2\right] \xrightarrow{Tautomerises} \underset{Butan-2-one}{CH_3CH_2-\overset{O}{\overset{\|}{C}}-CH_3}$$

35. Ethyne to pentan-2-one

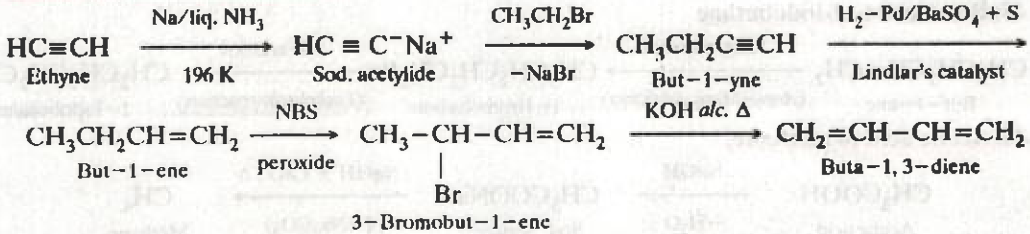
First convert ethyne to but-1-yne as shown in conversion **18** and then convert it into pentan-2-one as follows :



$$\underset{But-1-yne}{CH_3CH_2C\equiv CH} \xrightarrow[196\ K]{Na/liq.\ NH_3} CH_3CH_2C\equiv C^-Na^+ \xrightarrow{CH_3I} \underset{But-2-yne}{CH_3CH_2C\equiv CCH_3}$$

$$\xrightarrow[\substack{333\ K\\ (Addition\ of\ H_2O)}]{Dil.\ H_2SO_4,\ HgSO_4} \left[CH_3CH_2CH=\overset{OH}{\overset{|}{C}}-CH_3\right] \xrightarrow{Tautomerises} \underset{Pentan-2-one}{CH_3CH_2CH_2-\overset{O}{\overset{\|}{C}}-CH_3}$$

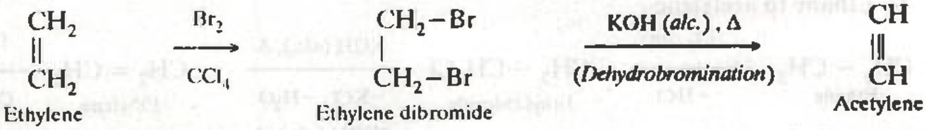
36. Ethyne to buta-1, 3-diene



$$\underset{Ethyne}{HC\equiv CH} \xrightarrow[196\ K]{Na/liq.\ NH_3} \underset{Sod.\ acetylide}{HC\equiv C^-Na^+} \xrightarrow[-NaBr]{CH_3CH_2Br} \underset{But-1-yne}{CH_3CH_2C\equiv CH} \xrightarrow[Lindlar's\ catalyst]{H_2-Pd/BaSO_4+S}$$

$$\underset{But-1-ene}{CH_3CH_2CH=CH_2} \xrightarrow[peroxide]{NBS} \underset{3-Bromobut-1-ene}{CH_3-\underset{\underset{Br}{|}}{CH}-CH=CH_2} \xrightarrow{KOH\ alc.\ \Delta} \underset{Buta-1,\ 3-diene}{CH_2=CH-CH=CH_2}$$

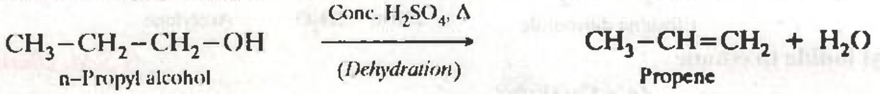
37. Ethylene to acetylene



$$\underset{Ethylene}{\begin{matrix}CH_2\\ \|\\ CH_2\end{matrix}} \xrightarrow[CCl_4]{Br_2} \underset{Ethylene\ dibromide}{\begin{matrix}CH_2-Br\\ |\\ CH_2-Br\end{matrix}} \xrightarrow[(Dehydrobromination)]{KOH\ (alc.),\ \Delta} \underset{Acetylene}{\begin{matrix}CH\\ |||\\ CH\end{matrix}}$$

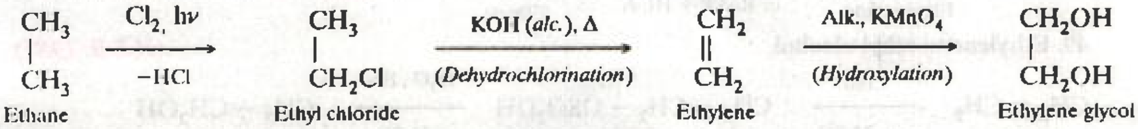
(D.S.B. 1981, 83)

38. n-Propyl alcohol to propene



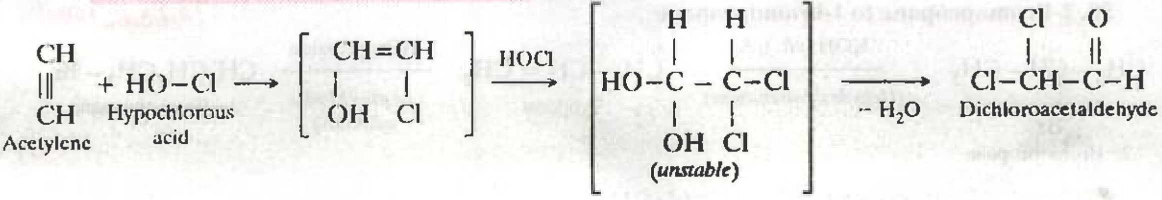
$$\underset{n-Propyl\ alcohol}{CH_3-CH_2-CH_2-OH} \xrightarrow[(Dehydration)]{Conc.\ H_2SO_4,\ \Delta} \underset{Propene}{CH_3-CH=CH_2} + H_2O$$

39. Ethane to ethylene glycol



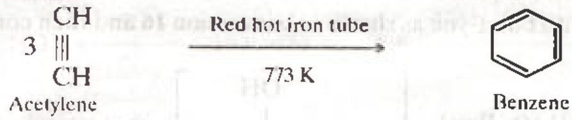
$$\underset{Ethane}{\begin{matrix}CH_3\\ |\\ CH_3\end{matrix}} \xrightarrow[-HCl]{Cl_2,\ h\nu} \underset{Ethyl\ chloride}{\begin{matrix}CH_3\\ |\\ CH_2Cl\end{matrix}} \xrightarrow[(Dehydrochlorination)]{KOH\ (alc.),\ \Delta} \underset{Ethylene}{\begin{matrix}CH_2\\ \|\\ CH_2\end{matrix}} \xrightarrow[(Hydroxylation)]{Alk.,\ KMnO_4} \underset{Ethylene\ glycol}{\begin{matrix}CH_2OH\\ |\\ CH_2OH\end{matrix}}$$

40. Acetylene to dichloroacetaldehyde



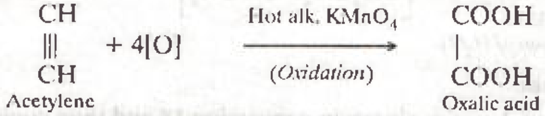
$$\underset{Acetylene}{\begin{matrix}CH\\ |||\\ CH\end{matrix}} + \underset{Hypochlorous\ acid}{HO-Cl} \longrightarrow \left[\begin{matrix}CH=CH\\ |\qquad |\\ OH\quad Cl\end{matrix}\right] \xrightarrow{HOCl} \underset{(unstable)}{\left[\begin{matrix}H\quad\ H\\ |\qquad |\\ HO-C-C-Cl\\ |\qquad |\\ OH\quad Cl\end{matrix}\right]} \xrightarrow[-H_2O]{} \underset{Dichloroacetaldehyde}{\begin{matrix}Cl\quad O\\ |\quad\ \|\\ Cl-CH-C-H\end{matrix}}$$

41. Acetylene to benzene



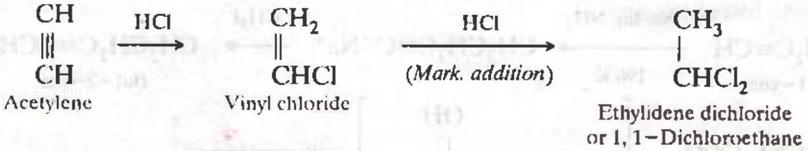
$$3\,\underset{\text{Acetylene}}{\begin{array}{c}CH\\ |||\\ CH\end{array}} \xrightarrow[773\text{ K}]{\text{Red hot iron tube}} \text{Benzene}$$

42. Acetylene to oxalic acid



$$\underset{\text{Acetylene}}{\begin{array}{c}CH\\ |||\\ CH\end{array}} + 4[O] \xrightarrow[(\textit{Oxidation})]{\text{Hot alk. }KMnO_4} \underset{\text{Oxalic acid}}{\begin{array}{c}COOH\\ |\\ COOH\end{array}}$$

43. Acetylene to ethylidene dichloride (1, 1-dichloroethane) *(P.S.B. 1987)*



$$\underset{\text{Acetylene}}{\begin{array}{c}CH\\ |||\\ CH\end{array}} \xrightarrow{HCl} \underset{\text{Vinyl chloride}}{\begin{array}{c}CH_2\\ ||\\ CHCl\end{array}} \xrightarrow[(\textit{Mark. addition})]{HCl} \underset{\substack{\text{Ethylidene dichloride}\\ \text{or 1, 1-Dichloroethane}}}{\begin{array}{c}CH_3\\ |\\ CHCl_2\end{array}}$$

44. Methane to trichloromethane (chloroform).

$$\underset{\text{Methane}}{CH_4} \xrightarrow[-HCl]{Cl_2/h\nu} \underset{\text{Chloromethane}}{CH_3Cl} \xrightarrow[-HCl]{Cl_2/h\nu} \underset{\text{Dichloromethane}}{CH_2Cl_2} \xrightarrow[-HCl]{Cl_2/h\nu} \underset{\text{Trichloromethane}}{CHCl_3}$$

45. But-1-ene to 1-iodobutane

$$\underset{\text{But-1-ene}}{CH_3CH_2CH{=}CH_2} \xrightarrow[(\textit{Anti-Mark. addition})]{\text{HBr, peroxide}} \underset{\text{1-Bromobutane}}{CH_3CH_2CH_2CH_2Br} \xrightarrow[(\textit{Finkelstein reaction})]{\text{KI/acetone}} \underset{\text{1-Iodobutane}}{CH_3CH_2CH_2CH_2I}$$

46. Acetic acid to methane

$$\underset{\text{Acetic acid}}{CH_3COOH} \xrightarrow[-H_2O]{NaOH} \underset{\text{Sod. acetate}}{CH_3COONa} \xrightarrow[\substack{(-Na_2CO_3)\\ (\textit{Decarboxylation})}]{NaOH + CaO,\,\Delta} \underset{\text{Methane}}{CH_4}$$

47. Ethane to acetylene

$$\underset{\text{Ethane}}{CH_3-CH_3} \xrightarrow[-HCl]{Cl_2,\,h\nu} \underset{\text{Ethyl chloride}}{CH_3-CH_2Cl} \xrightarrow[-KCl,\,-H_2O]{KOH\,(alc.),\,\Delta} \underset{\text{Ethylene}}{CH_2=CH_2} \xrightarrow[CCl_4]{Br_2}$$

$$\underset{\text{Ethylene dibromide}}{BrCH_2-CH_2-Br} \xrightarrow[-2KBr,\,-2H_2O]{2KOH\,(alc.),\,\Delta} \underset{\text{Acetylene}}{CH\equiv CH}$$

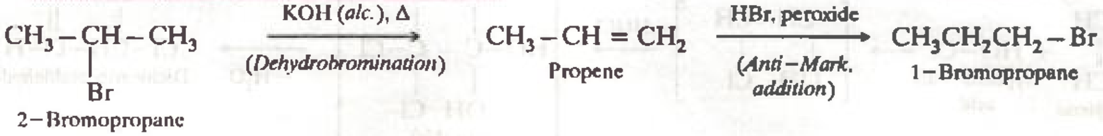
48. Ethyl iodide to ethane *(I.S.M. Dhanbad 1992)*

$$\underset{\text{Ethyl iodide}}{CH_3-CH_2I} \xrightarrow[\text{or Red P + HI, }\Delta]{\text{Zn - Cu/alcohol}} \underset{\text{Ethane}}{CH_3-CH_3}$$

49. Ethylene to ethyl alcohol *(H.S.B. 1987)*

$$\underset{\text{Ethylene}}{CH_2=CH_2} \xrightarrow[\text{conc. }H_2SO_4]{\text{Cold}} \underset{\text{Ethyl hydrogen sulphate}}{CH_3-CH_2-OSO_2OH} \xrightarrow[-H_2SO_4]{H_2O\text{, Boil}} \underset{\text{Ethyl alcohol}}{CH_3-CH_2OH}$$

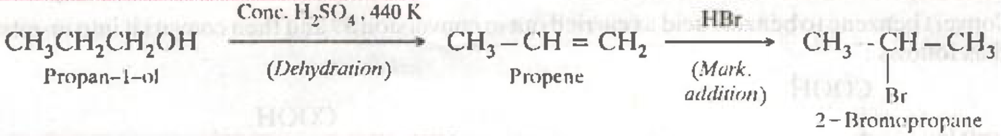
50. 2-Bromopropane to 1-bromopropane *(A.I.S.B. 1996)*



$$\underset{\text{2-Bromopropane}}{\begin{array}{c}CH_3-CH-CH_3\\ |\\ Br\end{array}} \xrightarrow[(\textit{Dehydrobromination})]{KOH\,(alc.),\,\Delta} \underset{\text{Propene}}{CH_3-CH=CH_2} \xrightarrow[\substack{(\textit{Anti-Mark.}\\ \textit{addition})}]{\text{HBr, peroxide}} \underset{\text{1-Bromopropane}}{CH_3CH_2CH_2-Br}$$

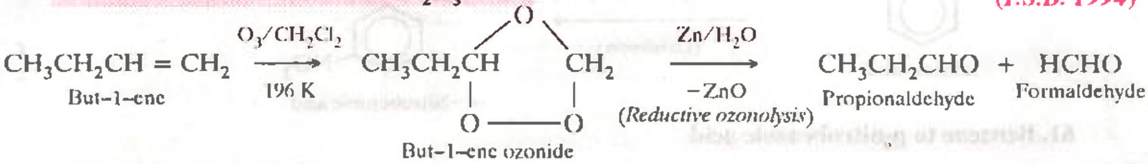
51. Propan-1-ol to 2-bromopropane

(D.S.B. 1996)



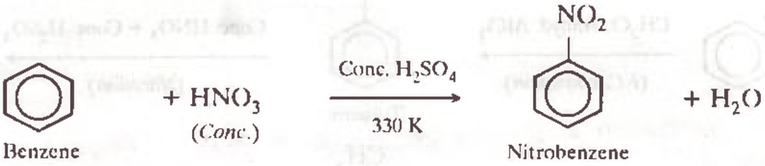
52. But-1-ene into HCHO and C_2H_5CHO

(P.S.B. 1994)



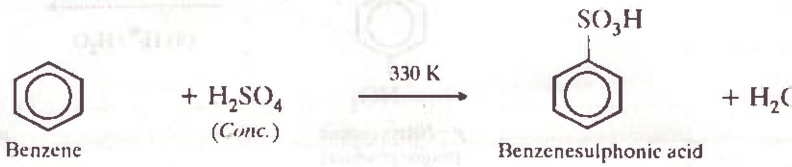
53. Benzene to nitrobenzene

(P.S.B. 1987)



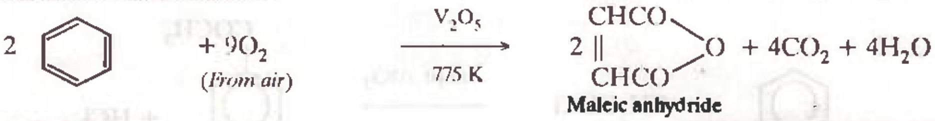
54. Benzene to benzenesulphonic acid

(P.S.B. 1987)



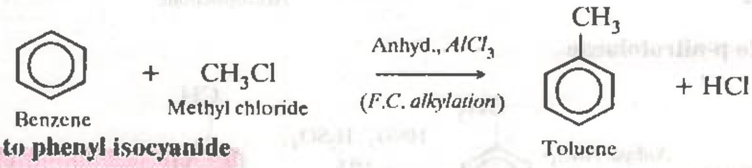
55. Benzene to maleic anhydride

(H.S.B. 1987)



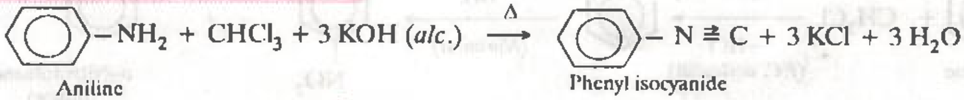
56. Benzene to toluene

(P.S.B. 1987, H.S.B. 1989)



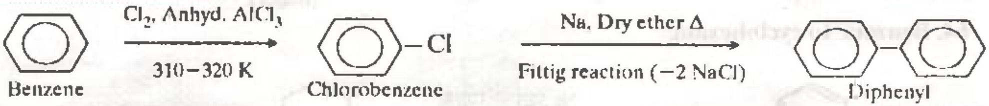
57. Aniline to phenyl isocyanide

(N.C.E.R.T.)



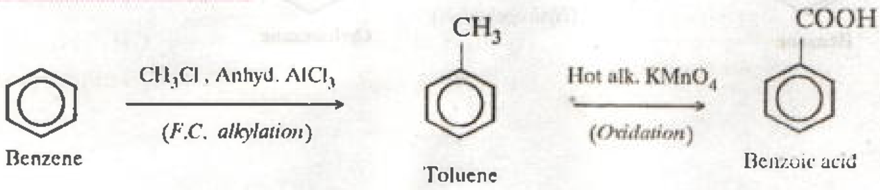
58. Benzene to diphenyl

(N.C.E.R.T.)



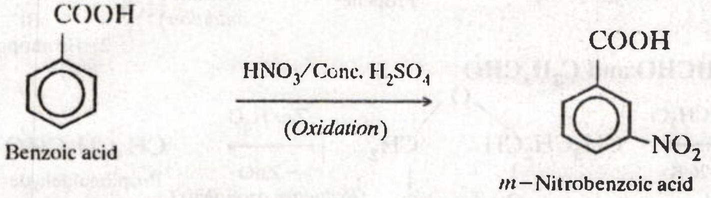
59. Benzene to benzoic acid

(H.S.B. 1989)

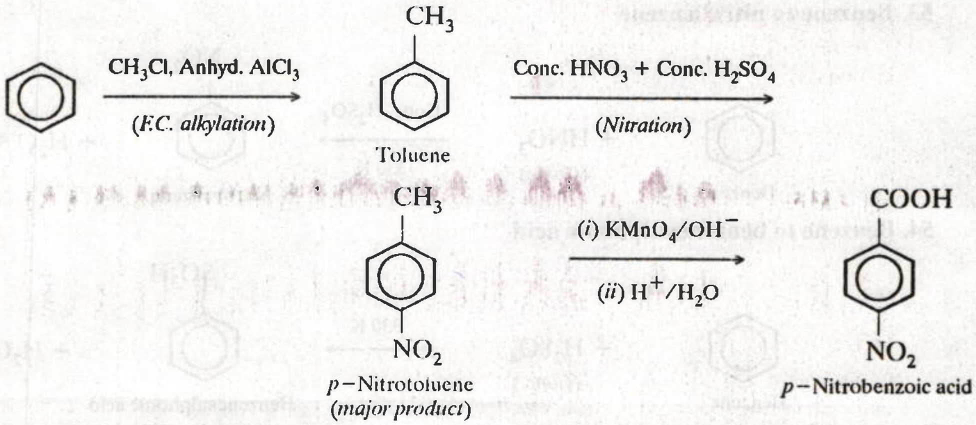


60. Benzene to m-nitrobenzoic acid

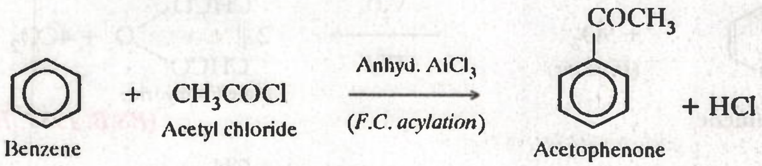
Convert benzene to benzoic acid as carried out in conversion 59 and then convert it into *m*-nitrobenzoic acid as follows :



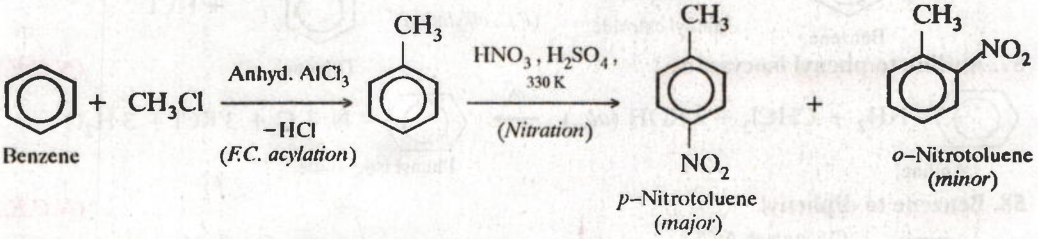
61. Benzene to p-nitrobenzoic acid



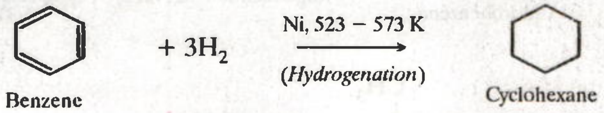
62. Benzene to acetophenone (*P.S.B. 1987, H.S.B. 1988*)



63. Benzene to p-nitrotoluene

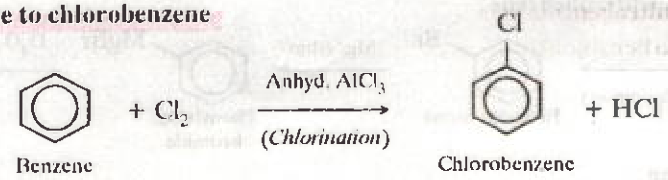


64. Benzene to cyclohexane

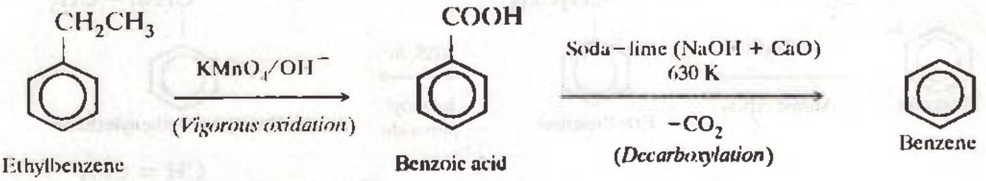


65. Benzene to chlorobenzene

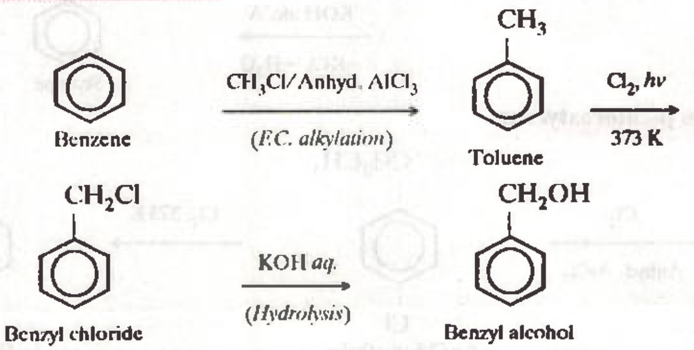
(H.S.B. 1989)



66. Ethylbenzene to benzene



67. Benzene to benzyl alcohol

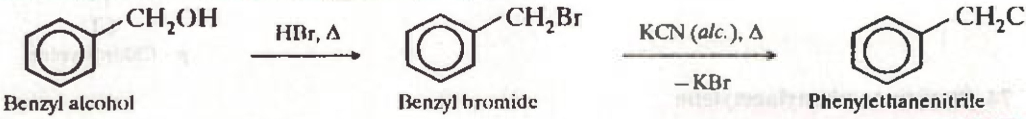


68. Toluene to benzyl alcohol

(N.C.E.R.T.)

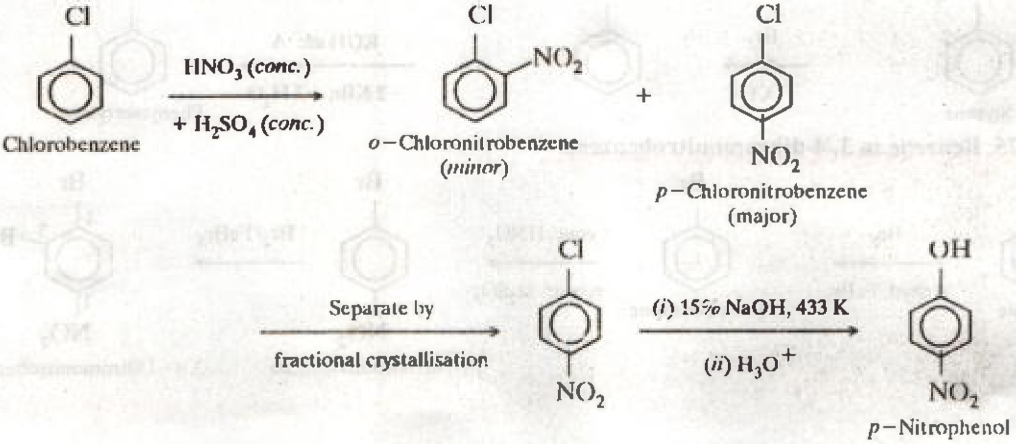
69. Benzyl alcohol to phenylethanenitrile

(N.C.E.R.T.)



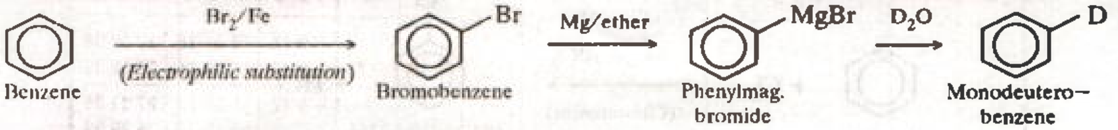
70. Chlorobenzene to p-nitrophenol

(N.C.E.R.T.)

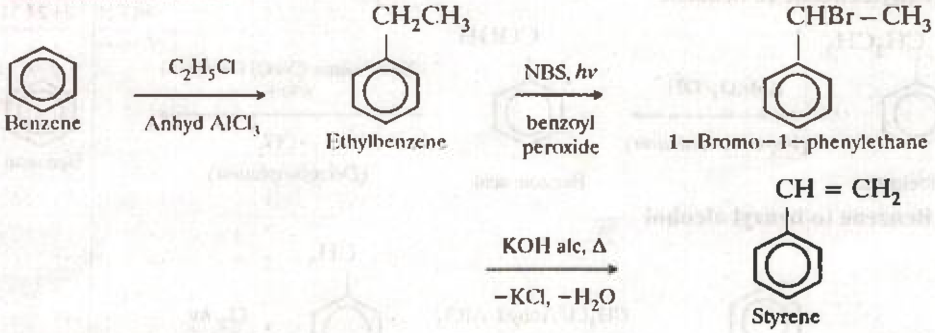


71. Benzene to monodeuterobenzene

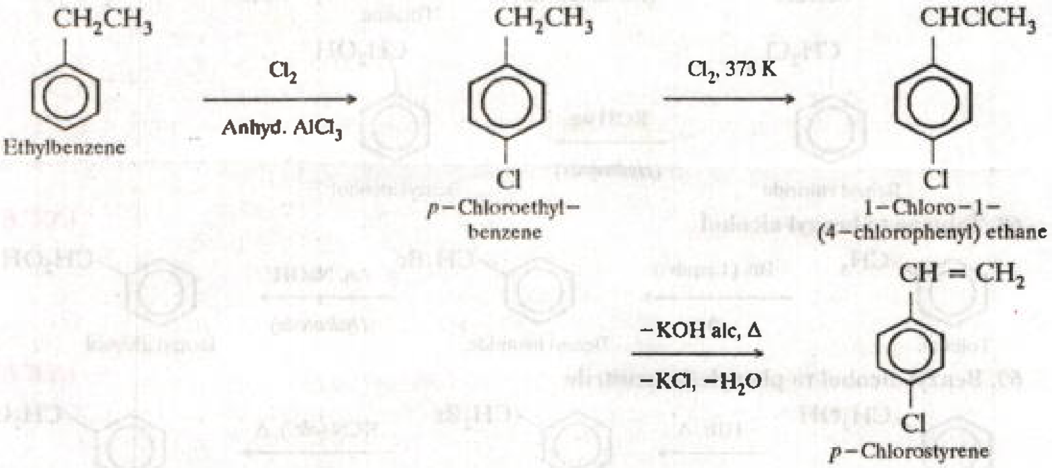
(N.C.E.R.T.)



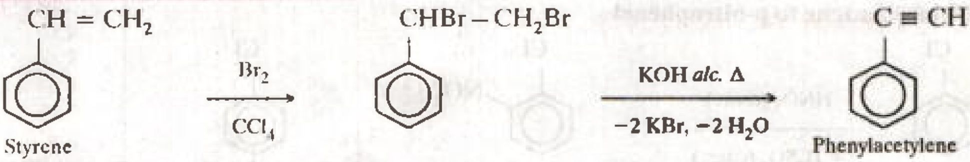
72. Benzene to styrene



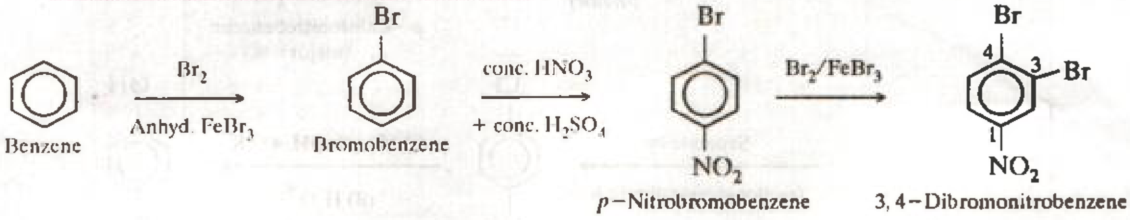
73. Ethylbenzene to p-chlorostyrene



74. Styrene to phenylacetylene



75. Benzene to 3, 4-dibromonitrobenzene



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11	0414	0453	0492	0531	0569						4	8	12	16	20	23	27	31	35
						0607	0645	0682	0719	0755	4	7	11	15	18	22	26	29	33
12	0792	0828	0864	0899	0934						3	7	11	14	18	21	25	28	32
						0969	1004	1038	1072	1106	3	7	10	14	17	20	24	27	31
13	1139	1173	1206	1239	1271						3	6	10	13	16	19	23	26	29
						1303	1335	1367	1399	1430	3	7	10	13	16	19	22	25	29
14	1461	1492	1523	1553	1584						3	6	9	12	15	19	22	25	28
						1614	1644	1673	1703	1732	3	6	9	12	14	17	20	23	26
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16	2041	2068	2095	2122	2148						3	6	8	11	14	16	19	22	24
						2175	2201	2227	2253	2279	3	5	8	10	13	16	18	21	23
17	2304	2330	2355	2380	2405						3	5	8	10	13	15	18	20	23
						2430	2455	2480	2504	2529	3	5	8	10	12	15	17	20	22
18	2553	2577	2601	2625	2648						2	5	7	9	12	14	17	19	21
						2672	2695	2718	2742	2765	2	4	7	9	11	14	16	18	21
19	2788	2810	2833	2856	2878						2	4	7	9	11	13	16	18	20
						2900	2923	2945	2967	2989	2	4	6	8	11	13	15	17	19
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5052	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
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37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
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42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
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48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
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LOGARITHMS

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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	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
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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
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93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
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.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
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.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	2266	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	2624	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

ANTILOGARITHMS

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
.50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228	1	1	2	3	4	4	5	6	7
.51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3304	1	2	2	3	4	5	5	6	7
.52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381	1	2	2	3	4	5	5	6	7
.53	3388	3396	3404	3412	3420	3428	3436	3443	3451	3459	1	2	2	3	4	5	6	6	7
.54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540	1	2	2	3	4	5	6	6	7
.55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622	1	2	2	3	4	5	6	7	7
.56	3631	3639	3648	3656	3664	3673	3681	3690	3698	3707	1	2	3	3	4	5	6	7	8
.57	3715	3724	3733	3741	3750	3758	3767	3776	3784	3793	1	2	3	3	4	5	6	7	8
.58	3802	3811	3819	3828	3837	3846	3855	3864	3873	3882	1	2	3	4	4	5	6	7	8
.59	3890	3899	3908	3917	3926	3936	3945	3954	3963	3972	1	2	3	4	5	5	6	7	8
.60	3981	3990	3399	4009	4018	4027	4036	4046	4055	4064	1	2	3	4	5	6	6	7	8
.61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159	1	2	3	4	5	6	7	8	9
.62	4169	4178	4188	4198	4207	4217	4227	4236	4246	4256	1	2	3	4	5	6	7	8	9
.63	4266	4276	4285	4295	4305	4315	4325	4335	4345	4355	1	2	3	4	5	6	7	8	9
.64	4365	4375	4385	4395	4406	4416	4426	4436	4446	4457	1	2	3	4	5	6	7	8	9
.65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560	1	2	3	4	5	6	7	8	9
.66	4571	4581	4592	4603	4613	4624	4634	4645	4656	4667	1	2	3	4	5	6	7	9	10
.67	4677	4688	4699	4710	4721	4732	4742	4753	4764	4775	1	2	3	4	5	7	8	9	10
.68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887	1	2	3	4	6	7	8	9	10
.69	4898	4909	4920	4932	4943	4955	4966	4977	4989	5000	1	2	3	5	6	7	8	9	10
.70	5012	5023	5035	5047	5058	5070	5082	5093	5105	5117	1	2	4	5	6	7	8	9	11
.71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236	1	2	4	5	6	7	8	10	11
.72	5241	5260	5272	5284	5297	5309	5321	5333	5346	5358	1	2	4	5	6	7	9	10	11
.73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483	1	3	4	5	6	3	9	10	11
.74	5495	5508	5521	5534	5546	5559	5572	5585	5598	5610	1	3	4	5	6	8	9	10	12
.75	5623	5636	5649	5662	5675	5689	5702	5715	5728	5741	1	3	4	5	7	8	9	10	12
.76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875	1	3	4	5	7	8	9	11	12
.77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012	1	3	4	5	7	8	10	11	12
.78	6026	6039	6053	6067	6081	6095	6109	6124	6138	6152	1	3	4	6	7	8	10	11	13
.79	6166	6180	6194	6209	6223	6237	6252	6266	6281	6295	1	3	4	6	7	9	10	11	13
.80	6310	6324	6339	6353	6368	6383	6397	6412	6427	6442	1	3	4	6	7	9	10	12	13
.81	6457	6471	6486	6501	6516	6531	6546	6561	6577	6592	2	3	5	6	8	9	11	12	14
.82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745	2	3	5	6	8	9	11	12	14
.83	6761	6776	6792	6808	6823	6839	6855	6871	6887	6902	2	3	5	6	8	9	11	13	14
.84	6918	6934	6950	6966	6982	6998	7015	7031	7047	7063	2	3	5	6	8	10	11	13	15
.85	7079	7096	7112	7129	7145	7161	7178	7194	7211	7228	2	3	5	7	8	10	12	13	15
.86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396	2	3	5	7	8	10	12	13	15
.87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568	2	3	5	7	9	10	12	14	16
.88	7586	7603	7621	7638	7656	7674	7691	7709	7727	7745	2	4	5	7	9	11	12	14	16
.89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925	2	4	5	7	9	11	13	14	16
.90	7943	7962	7980	7998	8017	8035	8054	8072	8091	8110	2	4	6	7	9	11	13	15	17
.91	8128	8147	8166	8185	8204	8222	9241	8260	8279	8299	2	4	6	8	9	11	13	15	17
.92	8318	8337	8356	8375	8395	8414	8433	8453	8472	8492	2	4	6	8	10	12	14	15	17
.93	8511	8531	8551	8570	8590	8610	8630	8650	8670	8690	2	4	6	8	10	12	14	16	18
.94	8710	8730	8750	8770	8790	8810	8831	8851	8872	8892	2	4	6	8	10	12	14	16	18
.95	8913	8933	8954	8974	8995	9016	9036	9057	9078	9099	2	4	6	8	10	12	15	17	19
.96	9120	9141	9162	9183	9204	9226	9247	9268	9290	9311	2	4	6	8	11	13	15	17	19
.97	9333	9354	9376	9397	9419	9441	9462	9484	9506	9528	2	4	7	9	11	13	15	17	20
.98	9550	9572	9594	9616	9638	9661	9683	9705	9727	9750	2	4	7	9	11	13	16	18	20
.99	9772	9795	9817	9840	9863	9886	9908	9931	9954	9977	2	5	7	9	11	14	16	18	20

1. SEFI

The nited State Education Foundation in India

2. British Council

3. IDP Education Australia Ltd.

$Fe_2(SO_4)_3$ used in water & sewage treatment

Density of water = 1g/cm³

Drainer Cleaner (Drainex)

$2Al + 2NaOH + 2H_2O \rightarrow 2NaAlO_2 + 3H_2$

Urea

$NH_2-CO-NH_2$

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