

Real world link

The atmospheric gases, which are used in respiration and photosynthesis are called 'air'. Air is responsible for life on earth. Without air, we cannot imagine life on earth. During the process of respiration, we breathe in oxygen and exhale carbon dioxide. Carbon dioxide is absorbed by plants and used in the preparation of their food. Decrease in the number of plants increases the amount of carbon dioxide in the air and atmospheric composition will change, which will cause problems in the form of pollution.

14.1 Composition of the Atmosphere

The composition of atmosphere is variable. It changes according to the time and place. The atmosphere is the mixture of different types of gases, including water vapours and dust particles. Nitrogen and Oxygen are the two main gases of the atmosphere. 99 % of atmosphere is made up of these two gases. Other gases like Argon, carbon dioxide, hydrogen, neon, helium etc. form the remaining part of atmosphere. The mass of atmosphere is approximately 4.5 to 5×10^{15} metric tonnes; the density of atmosphere is 0.0013 g/cm^3 . Which gradually decrease with altitude. The details of different gases of the atmosphere are given in the table 14.1 and in Fig.14.1.

Table 14.1 Percentages by volume of Gases in the Dry Air

Serial No.	Gases	Amount (in percentage)
A.	Main Gases	
1.	Nitrogen	78.1
2.	Oxygen	20.9
		} 99%
B.	Secondary Gases	
1.	Argon	0.9
2.	Carbon Dioxide	0.03
3.	Hydrogen	0.01
4.	Neon	0.0018
5.	Helium	0.0005
6.	Ozone	0.00006
7.	Others	
		} 0.99%
C.	Water Vapours	0.0 to 4%

Atmospheric Composition

Percentages of gases that make up Earth's Atmosphere

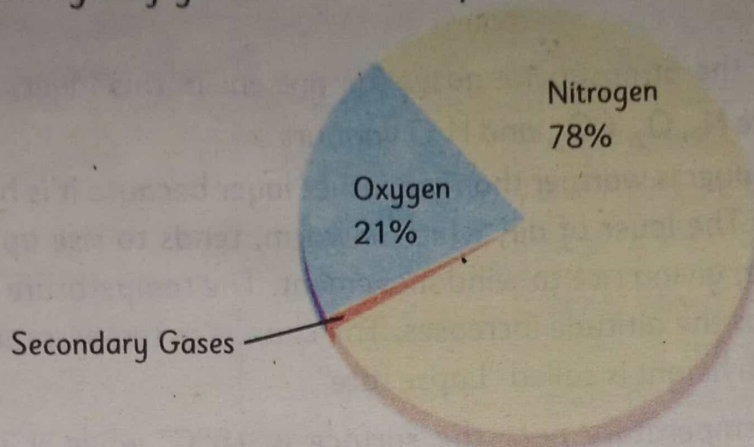


Fig.14.1 Atmospheric Composition of Gases

14.2 Layers of the Atmosphere

The atmosphere is an important part of the earth. It surrounds the earth from all sides. Generally, it extends up to about 500 km from the earth's surface. The atmosphere can be divided into many layers based on the variation in temperature (-92°C to 1200°C) in each layer. The pressure of atmosphere at the sea level is 1 atm but at high altitude, it decreases. The atmosphere can be divided into the following four layers or zones.

1. Troposphere
2. Stratosphere
3. Mesosphere
4. Thermosphere / Ionosphere

Here you will study only two layers.
These layers are,

- (a) Troposphere (b) Stratosphere

14.2.1 Troposphere

The first layer of the atmosphere, which is closest to the surface of earth, is called troposphere. Tropo means turning or changing. The conditions in this layer are more variable than any other layer of the atmosphere. We live in troposphere. Few characteristics of troposphere are following.

- i. The average height of this layer from the earth's surface is about 11 km. It heights depends upon the latitudes, seasons and pressure.

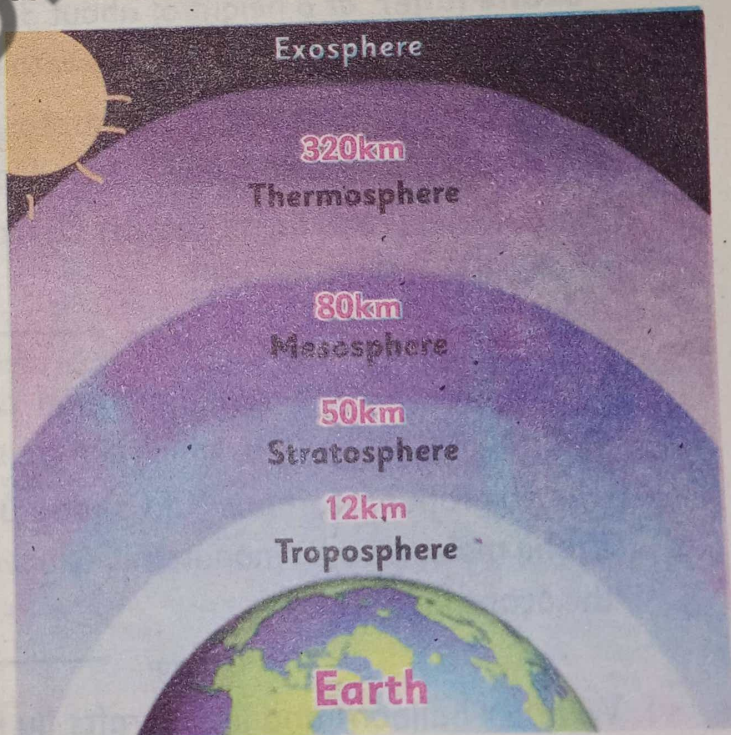


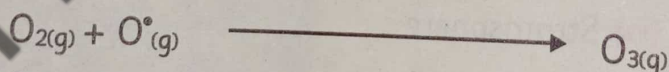
Fig.14.2 Layers of Atmosphere

- ii. Almost all of the dust particles and water vapours are present in this layer.
- iii. All weather phenomenon like cloud formation, winds, rainfall, snowfall takes place in this layer.
- iv. 70 to 75% of the atmospheric gases are present in this layer. Major components of troposphere are N_2 , O_2 , CO_2 , and H_2O vapours.
- v. The air of this layer is warmer than any other layer because it is heated from the earth's surface below. The layer of air, which is warm, tends to rise up and cold air flows to cover the space, giving rise to wind movement. The temperature decreases at a rate of $6.5^\circ C$ per km as the altitude increases. The change in temperature of atmosphere with an increase with height is called "Lapse rate".
- vi. The average temperature near the surface is $15^\circ C$, while it is $-56^\circ C$ at the top. Pressure, moisture content and density of air also decrease with height. Because of this, people experience difficulty in breathing at high altitudes in mountains.

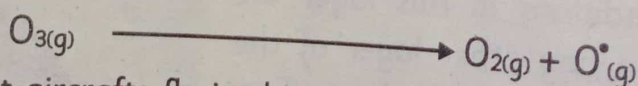
14.2.2 Stratosphere

The second layer of atmosphere which is above the troposphere is called Stratosphere (Strato = spread out).

- i. It starts at the top of troposphere and extends from 11km to 50km above the sea level.
- ii. The major component of stratosphere is ozone " O_3 ". The stratosphere contains the **ozone layer**; at a height of about 30 km, therefore it is also called ozonosphere. The concentration of ozone increases with the increase of height and is maximum at 30km.
- iii. The ozone is produced in the stratosphere, when the oxygen molecules (O_2) absorb Ultraviolet radiations (UV) and decompose to give atomic oxygen ($O^\bullet$), which immediately reacts with another O_2 molecule and results in the formation of ozone (O_3) molecule.



- iv. Ozone absorbs UV-radiations and protects us from harmful effects of ultraviolet radiations from the sun, which can cause skin cancer and damage to vegetation.
- v. The chlorofluorocarbons (CFCs) and ultraviolet radiations from the sun, break down ozone molecule into monatomic oxygen and diatomic oxygen, resulting in damage to the ozone layer.



- vi. Weather balloons and jet aircrafts fly in this region, as the air present in this layer is very thin. This increases the fuel efficiency of the aircrafts. In stratosphere, the temperature increases from $-56^\circ C$ to $-2^\circ C$ with height. The increase in temperature is due to the presence of ozone, which absorbs the UV – radiations of the sun.

Table 14.2 Components of the Atmosphere

Atmospheric layer	Height from the earth surface in km	Temperature range in Celsius ($^{\circ}\text{C}$)	Components
Troposphere	0 to 11	15 to -56	Layer closest to earth surface, ends at the tropopause (upper edge of troposphere)
Stratosphere	11 to 50	-56 to -2	Layer above the troposphere, contains the ozone layer, and ends at the stratopause
Mesosphere	50 to 85	-2 to -92	Layer above the stratosphere, ends at the mesopause.
Thermosphere	85 to 500	-92 to 1200	Layer above the mesosphere, absorbs solar radiation.

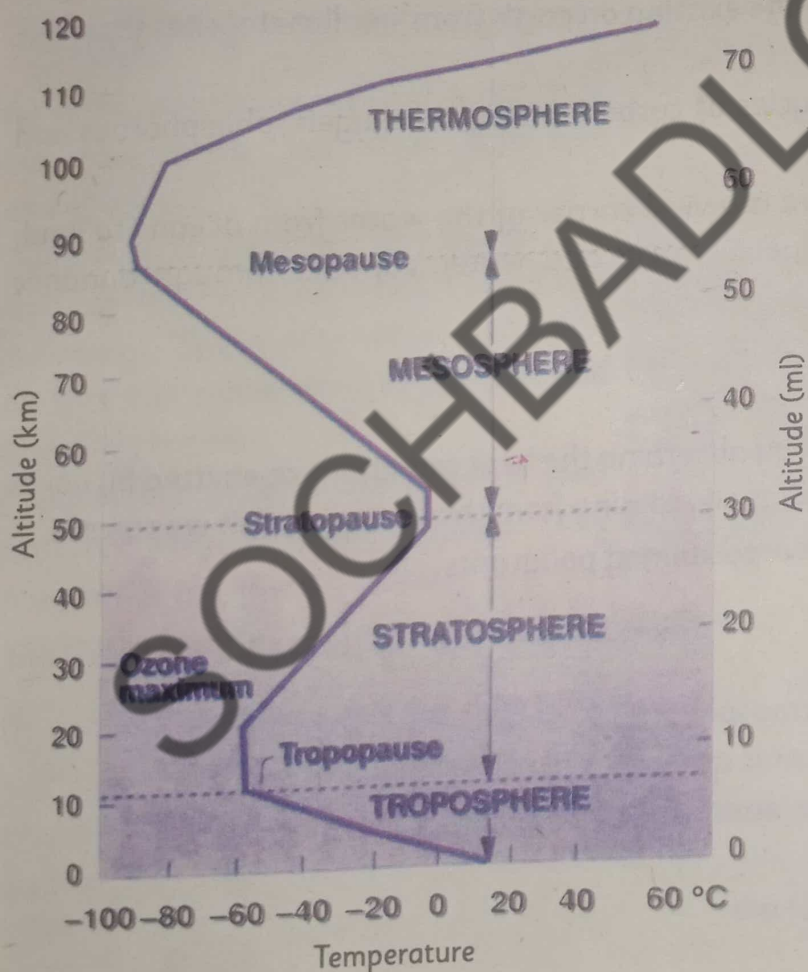


Fig.14.3 Earth's Atmosphere layer and temperature variations

Tidbit

- Exosphere is beyond thermosphere layer, it is a transitional space between earth's atmosphere and outer space.
- Due to the presence of ions, the thermosphere is also called ionosphere.

Importance of the Atmosphere

The atmosphere plays an important role for living organisms and it protects life on earth by serving the following functions:

- Oxygen is very important for living beings. Carbon dioxide is essential for the plants, nitrogen is also useful macronutrient for plants.
- The amount of water vapours in the atmosphere goes on changing and directly affects the plants and living beings.
- Ozone protects all kinds of life on the earth from the harmful ultraviolet rays of the sun.
- Ozone absorbs the energetic ultraviolet radiation, while allow the passing of important visible radiations.
- It keeps the earth's surface warm through heat retention, making possible a comfortable average temperature of $\pm 15^{\circ}\text{C}$.
- It prevents excessive heating of surface of the earth at day and excessive cooling at night thereby reducing the temperature variations.
- It contains nitrogen, oxygen and carbon dioxide gases important for plants growth and for respiration.
- It protects the surface of earth and all life existing on earth from small meteorites that heat up in the atmosphere due to friction.
- It serves as an integral part in the cycles of carbon, nitrogen, oxygen, phosphorous and sulphur on earth.
- It helps in flow of energy. Atmosphere is a vital carrier of the water from oceans to land, which is very important for hydrological cycle and water vapours through dynamic processes of airflow.
- It helps in radio communication.
- It helps in movement of aircrafts.
- It maintains the heat balance of earth by absorbing the heat radiations re-emitted by earth surface. Atmosphere allows visible radiations coming from the sun as a result we can see.
- It aids in removal, dispersion and decomposition of pollutants.

Self Assessment

1. What is the composition of the atmosphere?
2. Name the different layers of the atmosphere?
3. Explain stratosphere and write the composition of this layer.
4. Summarize the troposphere layer.
5. Explain the importance of atmosphere.

14.3 Air Pollution

Pollution is defined as the excess discharge of any substance into the environment, which adversely affects the quality of the environment and causes damage to humans, plants and animals.

Air pollution is the change of composition of air by the addition of harmful substances like carbon monoxide (CO), carbon dioxide (CO₂), nitrogen oxides (NO_x), sulphur dioxide (SO₂), hydrocarbons and particulate matter etc.

According to world health organization (WHO), Air pollution may be defined as "The substances released to air either by human activities or by natural activities, in sufficient concentration to cause harmful effects to human beings, vegetation (plants) and other living things."

Air pollution is a change in the physical, chemical and biological characteristics of air that causes adverse effects on humans and other organisms.

Reading Check

What is pollution? Also define air pollution.

14.3.1 Major Air Pollutants

Air pollutants are gases and particles in the atmosphere that harm organisms and affect climate.

The substances that are responsible for causing air pollution are called air pollutants. These are substances in the air that can cause harm to humans and the environment.

Pollutants can be in the form of solid particles, liquid droplets, or gases. They may be natural or man-made.

Types of Air Pollutants

Air pollutants can be classified into two types, primary and secondary pollutants.

i. Primary Pollutants

Primary pollutants are substances, which are released directly into air or directly produced from a process, such as ash from a volcanic eruption, the carbon monoxide gas from a motor vehicle exhaust or sulphur dioxide released from factories.



Fig.14.4 Air Pollution

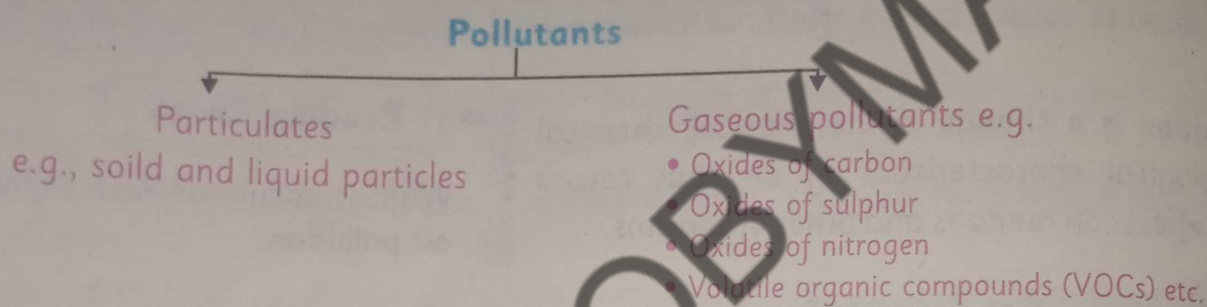
Major primary pollutants produced by human activities include Sulphur oxides (SO_x), Nitrogen oxides (NO_x), Carbon monoxide, Carbon dioxide (CO_2) and Volatile organic compounds.

ii. Secondary Pollutants

Secondary pollutants are not produced directly. Secondary pollutants are formed from the primary pollutants. They are formed in the air when primary pollutants react or interact with each other or with other substances.

An important example of secondary pollutants is ground level ozone, which is one of the many secondary pollutants that make up the photochemical smog. Besides this the acid rain is another example of secondary pollutants.

The different types of air pollutants on the basis of state of matter are following.



These different types of air pollutants are produced by two major sources, which are, natural sources and man-made sources.

Society, Technology And Science

Incineration of Waste Material Contributes to the Problem of Air Pollution

Incineration is a waste treatment process that involves the combustion of organic substances contained in waste materials. Incineration of waste materials converts the waste into ashes, flue gases and heat. The ash is mostly formed by the inorganic constituents of the waste and form of solid lumps or particulates carried by the flue gases. The flue gases include carbon dioxide (CO_2), carbon monoxide (CO), sulphur dioxide (SO_2) and large amount of particulate matters.

Incinerators reduce the solid mass of the original waste by 80 to 85% and convert the waste material into ash, flue gases and heat. During combustion, in incinerators hundreds of new compounds are formed which are extremely toxic and dangerous for health and environment.

Scientists and experts have identified hundreds of hazardous substances that are contributed to the environment and pollute the air.

It is suggested that the incinerators waste material may be treated before subjected into the environment. These flues gases may be absorbed, before adding into air.

14.3.2 Sources of Air Pollutants

A. Natural Sources

Natural processes e.g. rotting vegetation, volcanic eruption etc contribute specific amount of substances, which are considered pollutants. These are,

i. Particulates

The natural sources of particulate pollutants are volcanic eruptions, soil erosion by wind, dust storms, natural forests fires and salts spray from oceans etc. The contribution of the natural sources towards the particulate emission is greater than man-made sources. It has been estimated that natural sources release millions of tonnes particulate matter every year in air.

ii. Oxides of Carbon (CO_x)

(a). **Carbon monoxide:** The natural source of this gas is not very large. A very small amount of this gas is produced in volcanic eruptions, and decomposition of organic compounds, electrical discharge during storms, seed germination, natural gas emission etc.

(b). **Carbon dioxide:** The natural sources of CO_2 are animal and plant respiration, decomposition of organic matter, forest fires and emissions from volcanic eruptions.

iii. Oxide of nitrogen (NO_x)

The main sources for emission of oxides of nitrogen are bacteria and other microorganisms. Some of them convert the nitrates in soil into oxides of nitrogen of the atmosphere, while other converts the atmospheric nitrogen gas into oxides of nitrogen and ammonia.

iv. Sulphur oxides (SO_x)

The main sources of sulphur oxides are volcanic eruptions; they produce large quantities of sulphur dioxide (SO_2) into the air. Beside these SO_x is also produced by rock weathering and biological activities etc.

v. Volatile organic compounds (VOCs)

Volatile organic compounds (VOCs) such as methane produced by wetlands are the largest natural source. They contribute to 78% of natural methane in the environment. Animals like cows, sheep and goats during their normal digestion process produce large amounts of methane. Termites also contribute methane to the environment.

B. Anthropogenic / Man-Made Sources

Man-Made Sources mostly related to burning different kinds of fuels. These include, e.g. burning of coal and factories smoke, vehicles exhaust etc

i. Particulates

The man-made sources of particulate pollutants are combustions of fuels, wood burning, constructions, mining, industrial process, mountain blasting etc.

ii. Oxides of Carbon (CO_x)

(a). Carbon monoxide: Many human activities are responsible for the production of CO. Automobile exhausts to the environment produce 75% of this gas. Besides this incomplete combustion of fossil fuels, smoking forest fires and steel industries are the main contributors of this gas to the environment.

(b). Carbon dioxide: The main sources of CO₂ gas emission are our everyday activities such as cooking, baking etc. In addition to these, vehicle and industrial emissions, petroleum production, thermal power generation etc. are also sources of CO₂ emission.

iii. Oxide of Nitrogen (NO_x)

The main sources of oxides of nitrogen are automobiles exhausts, industrial activities, furnaces, thermal power generations, jet airplanes etc.

iv. Sulphur oxides (SO_x)

The main sources of sulphur oxides are the burning of fossil fuels such as coal, oil and natural gas. Coal fired power stations, in particular, are major sources of sulphur dioxide (SO₂). About 32% of total Sulphur oxides pollution is caused by man-made sources. Other man-made sources are transportation, industries and combustion of other sulphur containing compounds.

v. Volatile Organic Compounds (VOCs)

Volatile organic compounds such as methane etc are produced wherever there are fossil fuels burning, mining, or extraction. These are released to the atmosphere whenever fossil fuels are extracted from the earth, whether it is natural gas, coal or petroleum. In addition to that, the automobile exhausts are the main sources of volatile organic compounds to the atmosphere.

vi. CFCs (Chloro-Fluoro Carbons)

Chlorofluorocarbons (CFCs) are a group of compounds, which contain the elements Chlorine, Fluorine and Carbon. At room temperatures, they are usually colourless gases or liquids, which evaporate easily.

CFCs are used for a number of commercial and industrial purposes. They are used as a propellant in aerosol sprays in foams, in refrigerators and in air-conditioners. Due to their chemically un-reactive nature, they are also used as a solvent. CFCs have been released to the atmosphere by the use of aerosols containing sprays and leakages from refrigerators and air-conditioners.

Chlorine in CFCs catalyzes the conversion of ozone to oxygen atom and oxygen molecule. This chlorine atom has the ability to destroy a large amount of ozone. Thus, causing depletion of ozone layer.

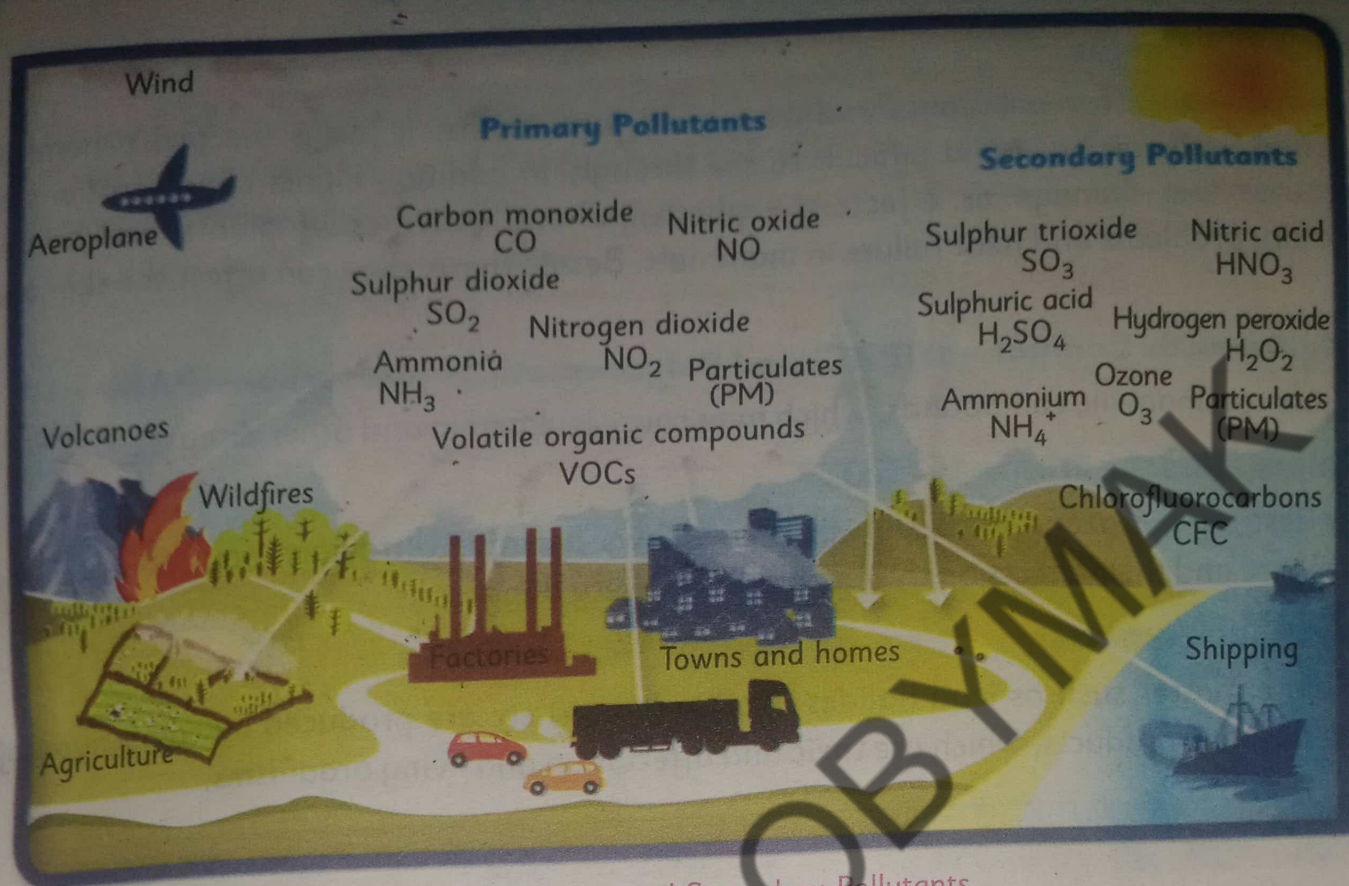


Fig.14.5 Primary and Secondary Pollutants

14.3.3 Effects of Air Pollutants

There are various harmful effects of the air pollutants. Some of them are,

i. Carbon monoxide

Carbon monoxide is a colourless, odourless, non-irritating but very poisonous gas. It affects the respiratory activity because haemoglobin has more affinity for CO to bind with itself than for oxygen. Thus, CO combines with haemoglobin and reduces the oxygen-carrying capacity of blood. This results in blurred vision, headache, nausea, unconsciousness and death. It also damages the central nervous system and heart.

ii. Carbon dioxide

Plants take in the carbon dioxide during the process of photosynthesis. This way they take away the excess carbon dioxide and helps in maintaining the oxygen-carbon dioxide ratio. If this ratio is disturbed by pollution; then increase in its concentration causes global-warming.

iii. Sulphur dioxide

It causes respiratory problems, irritation of eyes, nose and throat, pneumonia, asthma, severe headache, reduced productivity of plants, yellowing and reduced storage time of paper, yellowing and damage to limestone and marble, damage to leather, increased rate of corrosion of iron, steel, zinc, aluminium etc.

iv. Nitrogen Oxides

NO_x reacts with other pollutants and oxygen to form ozone. It forms the photochemical smog; makes the air hazy and difficult to see through. In addition higher concentrations of NO_x causes leaf damage or affects the photosynthetic activities of plants and causes respiratory problems and heart failure in mammals. Beside these, they can affect the skin and eyes.

v. Polyaromatic Compounds(PAC) and Polyaromatic Hydrocarbons(PAH)

These are carcinogenic compounds, which may cause leukaemia and other diseases.

vi. Chloro - fluoro carbons (CFCs)

These destroy the ozone layer, which then allows harmful Ultraviolet rays to enter the atmosphere and their effects on the earth could be very dangerous.

vii. Particulate matter

Particulate matter such as lead halides (lead pollution) etc are produced by combustion of leaded gasoline products, which are toxic and affect man and living organisms.

14.3.4 Environmental Effects of Pollutants

- i. Acid rain:** The rain having pH less than 5.6 is called an acid rain. Acid destroys vegetation and causes damage to human skin and hair etc. It also damages monuments and historical places.
- ii. Eutrophication:** It is the process of enrichment of water by salts that causes changes in the ecosystem such as increased production of algae and aquatic plants, decrease in the production of fishes and deterioration of the water quality.
- iii. Increase in Ground level ozone:** Breathing in increased ground ozone level can cause different health problems, particularly in children, such as asthma. Ground level ozone can also damage vegetation etc.
- iv. Green House Effect:** Gases, such as CO_2 , CH_4 , etc act like a green house around the earth. These gases trap the sun's rays and cause global warming.
- v. Global warming and increasing sea level:** Global warming adversely affects the climate changes such as the precipitation (rain and snow fall) and increase in temperature. The increase in temperature will ultimately melt the ice caps and glaciers. The sea level will rise and some big cities of the world may be drowned.
- vi. Ozone Depletion:** Pollutants also decrease the concentration of ozone below its normal level in stratosphere causing ozone depletion.

Self Assessment

1. Classify the air pollutants.
2. Differentiate between natural and man made sources of air pollutants.
3. What are the effects of air pollutants?

14.4 Acid Rain and its Effects

14.4.1 Acid rain

Normal rainwater is slightly acidic with a pH range of 5.6 to 6.0, because carbon dioxide and water present in the air react together to form carbonic acid, which is a weak acid. **When the pH level of rainwater falls below this range, it becomes acid rain.** Rain with pH as low as 2.1 has been reported. This value is lower than the pH of vinegar and lemon juice.

In common language, the acid rain means excessive acid in rainwater; it is one of the adverse effects of the air pollution. Acid rains are the result of excessive carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and smoke in the atmosphere because of burning of fossil fuels and industrial combustions. When these gases come in contact with water vapours, acids such as carbonic acid (H_2CO_3), sulphuric acid (H_2SO_4) and nitric acid

(HNO_3) are formed. These acids make the rainwater acidic. Acidity is determined on the basis of the pH level of the water droplets.

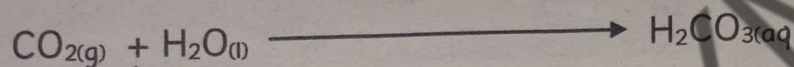
The atmosphere is always loaded with different types of pollutants like oxide of sulphur (SO_x), oxide of nitrogen (NO_x), carbon dioxide (CO_2) and carbon monoxide (CO) and other organic compounds.

Formation of Acid Rain

The acidic oxides of carbon, nitrogen and sulphur are highly soluble in water. These gases react with rainwater producing different acids.

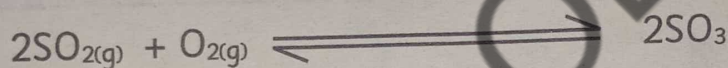
i. Acid Rain due to Carbon dioxide

The carbon dioxide reacts with water and form carbonic acid.



ii. Acid Rain due to Oxides of Sulphur (SO_x)

The sulphur dioxide gas (SO_2) reacts with oxygen in the atmosphere to form sulphur trioxide gas (SO_3).

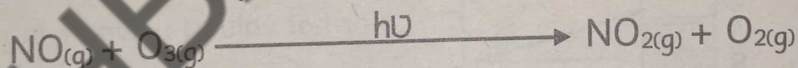


The sulphur trioxide (SO_3) is very reactive and soluble in rainwater to produce a strong acid, sulphuric acid (H_2SO_4).

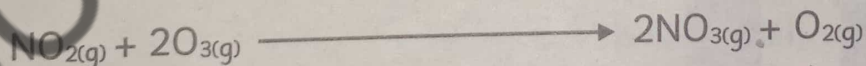


iii. Acid Rain due to Oxides of Nitrogen (NO_x)

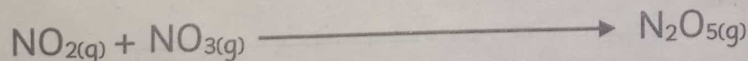
The nitric oxides react with ozone and produce nitrogen dioxide (NO_2) and oxygen (O_2).



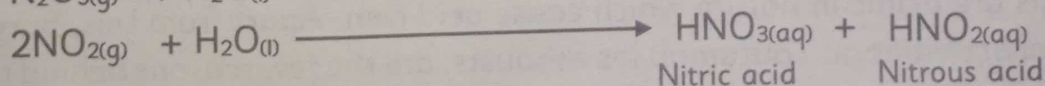
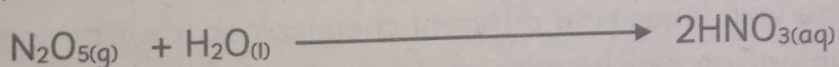
The nitrogen dioxide (NO_2) reacts with more ozone to form the nitrogen trioxide (NO_3) and oxygen, (O_2).



The nitrogen trioxide (NO_3) reacts with nitrogen dioxide (NO_2) to form the dinitrogen pentaoxide (N_2O_5).



The dinitrogen pentaoxide (N_2O_5) react with water present in the atmosphere to form the nitric acid (HNO_3).



Nitric acid

Nitrous acid

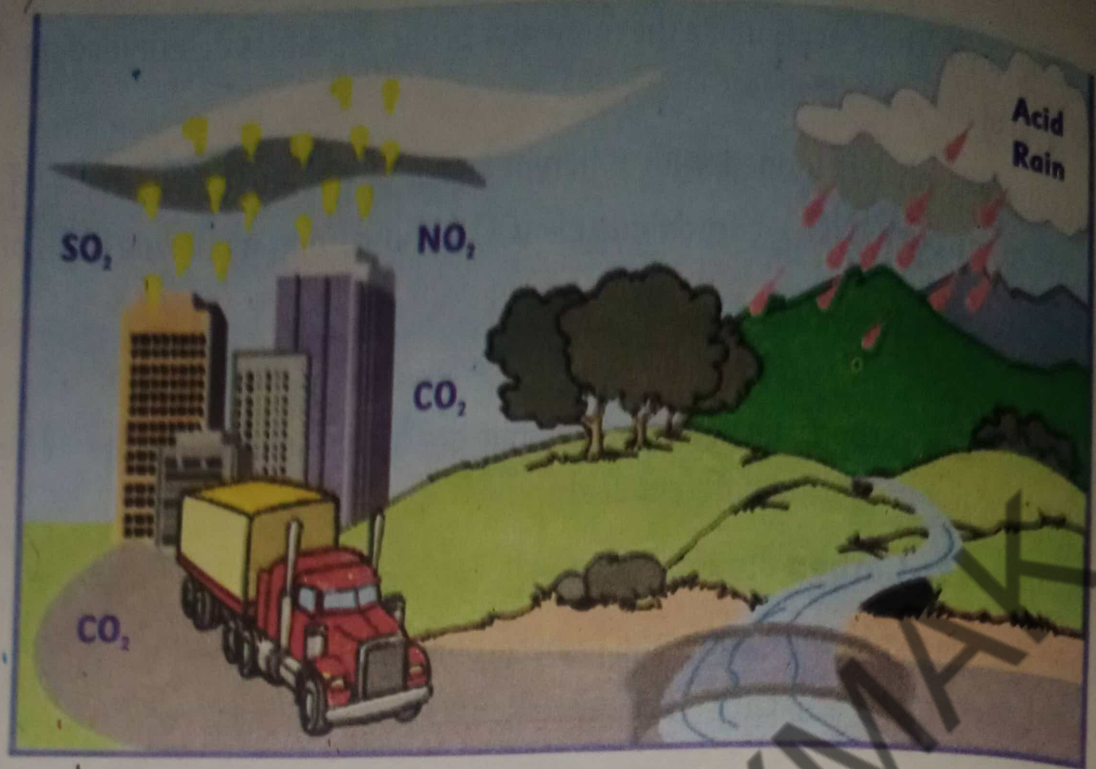


Fig.14.6 Acid Rain Formation

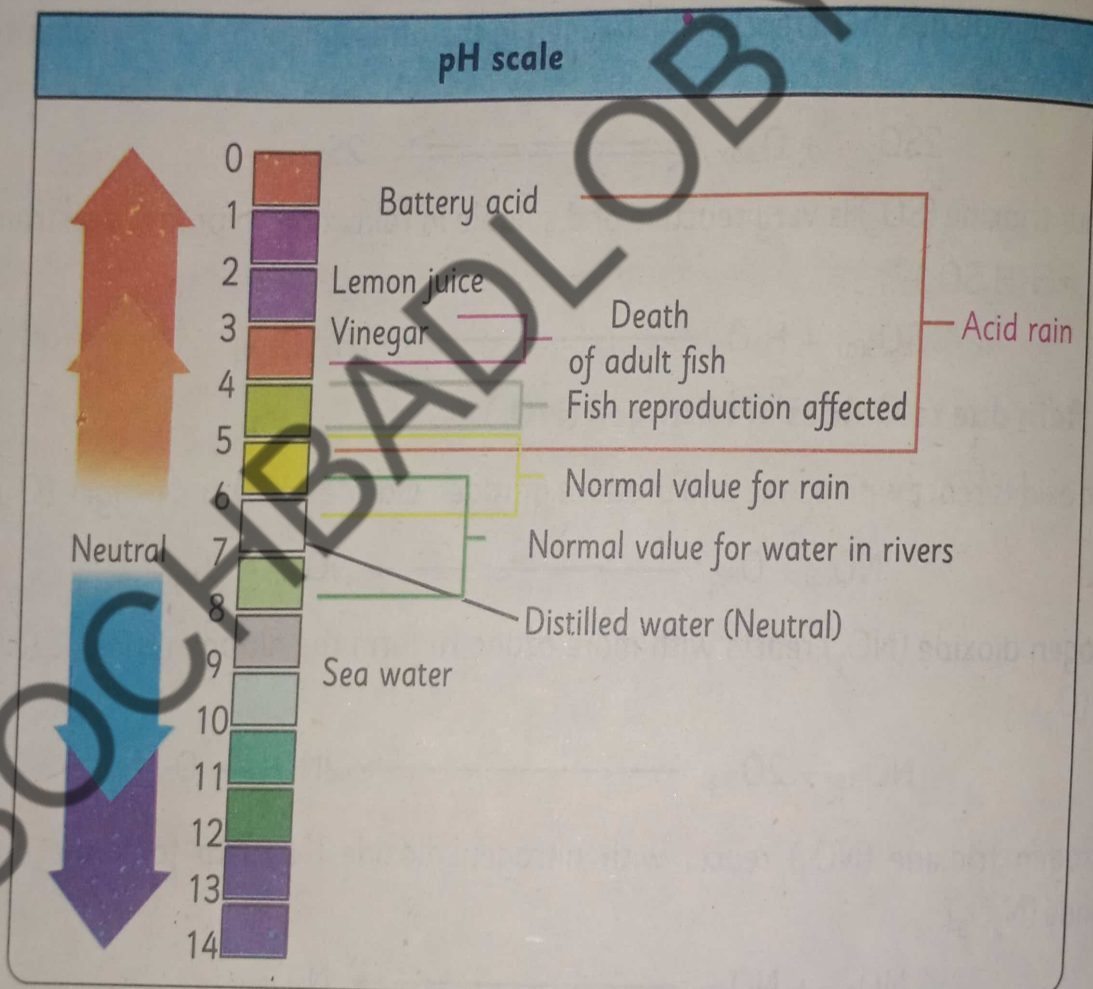


Fig.14.7 pH of Different Substances and Acid Rain

Acid rain generally leads to weathering of buildings, corrosion of metals and peeling of paints from surfaces. Erupting volcanoes emit different chemicals to the atmosphere. Some of these chemicals are acidic in nature which cause acid rain. Apart from this, burning of fossil fuels, industrial activities and automobiles exhausts, are the few reasons behind this activity.

14.4.2 Effects of Acid Rain on Fishes and Wildlife

The wildlife, aquatic life and other microorganisms are very sensitive to acidity. At pH – 5, most fish eggs cannot hatch. At lower pH levels, some adult fish die. Even if a species of fish or animal can tolerate moderately acidic water but the animals or plants they eat might not be available as food. For example, frog can tolerate the conditions at around pH – 4 but the **Mayflies** they eat are more sensitive and may not survive below pH – 5.6.



Fig.14.8 Effects of Acid Rain on Fishes

14.4.3 Effects of Acid Rain on Plants and Trees

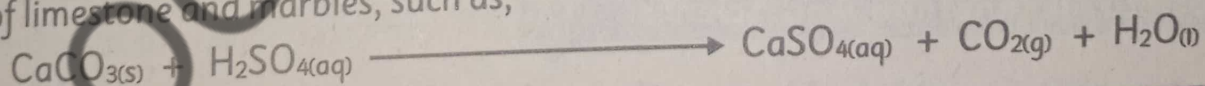
Plants are also damaged by acid rain. Acid rain removes minerals and nutrients from the soil that plants and trees need to grow. The young plants specially the newly growing buds and tips are very sensitive to acid rain. At high altitudes, acidic fog and clouds decrease nutrients from trees and plants, leaving them with brown or dead leaves and needles. These trees are then unable to absorb sunlight, which makes them weak and unable to survive at freezing temperatures.



Fig.14.9 Effects of Acid Rain on Plants and Trees

14.4.4 Effects of Acid Rain on Materials

Acid rain cause wide-ranging damage to buildings and sculptures as well as other things made of limestone and marbles, such as,



The calcium sulphate (CaSO_4) is soluble in water and washed away with rainwater. The deformation of historical statues in Greece and Italy and The Taj Mahal in India were reported to be eaten away and damaged due to acid rain. The acidic particles corrode metals and cause paint and stone to deteriorate more quickly.



Fig.14.10 Effect of Acid Rain on Statues



Fig.14.11 Effect of Acid Rain on the marble wall

14.4.5 Effects on Human

The acid rain mainly causes damage to lungs, skin and hair in human beings. The heavy metals released by acid may also cause potential threat to human health. Acid rain also increases the acidity of water which gives rise to waterborne diseases.

14.4.6 Effects on Soil

The acid rain increases the acidity of soil and thus affects the growth of plants.

Activity 14.2

Investigation of Acid rain

In this activity, we are going to test the effect of acid rain on a number of substances.

Materials:

Samples of chalk, marble chips, fresh green leaves, calcium oxide, zinc, iron, lead (or any other metal), dilute sulphuric acid, test tubes, beaker, dropper

Method:

1. Place a small sample of each of the following substances in a separate test tube: chalk, marble chips, fresh green leaves, calcium oxide, zinc, iron and lead.
2. To each test tube, add a few drops of dilute sulphuric acid with the help of dropper.
3. Observe what happens and record your results.

Discussion questions:

1. In which test tube reaction took place?
2. What happened to the sample substance?
3. What do your results tell you about the effect that acid rain could have on each of the following: buildings, soils, rocks and on plants ecosystem?
4. What precautions you suggest could be taken to reduce the impact of acid rain on these things?

Society, Technology And Science

Government Should do More to Control Air Pollution Resulting from Auto Exhaust.

Air pollution is the basic problem of today's world. In Pakistan, most of the big cities have crossed the permissible level of pollution. Clean air is a serious problem in Pakistan and especially in big and congested cities.

In big cities beside industrial pollution, auto exhaust is the most common air-polluting agent. The auto exhaust emission is directly contributing to the air pollution.

It is not only the duty of government to control it but every citizen also should make serious efforts to control the auto exhaust emissions.

On the government part, it is suggested that it should formulate short and long term planning to reduce the auto exhaust emission problems in big cities. Because without a healthy environment, there will be no healthy nation.

For effective control of auto exhaust emissions, it is suggested that,

1. The fuel quality may be improved and standardized.
2. In big cities, alternate fuels (solar, electric etc) transport system may be introduced.
3. Large vehicles such as buses or trains may be used as transport in big cities, so that people should avoid using their own vehicles, which contributes emissions to environment.
4. Government should encourage those persons who are developing, using or promoting the use of alternative fuels such as methanol, ethanol and bio-fuels.
5. The government must plan for producing such vehicles, which are using the alternate sources of fuels.
6. The government should take strict actions against those persons who are removing the vehicle silencer or not properly maintaining it.

14.5 Ozone Depletion and Its Effects

Ozone

Ozone (O_3) is an allotropic form of oxygen, consisting of three chemically bonded oxygen atoms. It was Schonbein (1840), who found that when an electric discharge was passed through oxygen (or air); a new gas of a strange smell is formed. He named this new gas as Ozone, which is derived from a Greek word *ozoaterr* meaning *smell* and the name ozone was given due to its irritating odour. The molecular formula of ozone is " O_3 " and molar mass is 48 g/mol.

The ozone gas in stratosphere combines and forms a layer called the ozone layer. The ozone layer saves the earth and the living organisms from harmful ultraviolet radiations of the sun.

Interesting facts

If all the ozone around the earth surface is condensed, it will form a layer of 2.5mm thickness on earth surface.

Tidbit

The major properties /characteristics of ozone gas are,

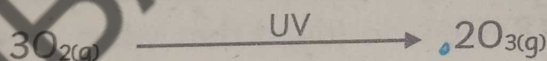
S. No	Property	characteristic
1.	Occurrence	Stratosphere – 30km
2.	Allotrope	Allotrope of oxygen
3.	Colour	Bluish
4.	Odour	Characteristic irritating
5.	Solubility	Soluble in water, turpentine oil, glacial acetic, and carbon disulphide (CS ₂)
6.	Liquefied	–112°C, pale blue colour liquid
7.	Effect on rubber	Harden the rubber, tyres and produce cracks in it

14.5.1 Occurrence of ozone

Ozone is present in the lower part of the stratosphere also called ozonosphere. In the stratosphere its concentration reaches to maximum concentration of 10 ppm (parts per million).

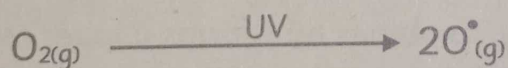
14.5.2 Ozone Formation

Ozone is formed naturally by chemical reactions involving solar ultraviolet radiation (sunlight) and oxygen molecules, which make up 21% of the atmosphere.

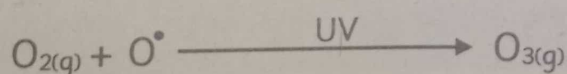


The formation of ozone occurs in two steps.

- i. **In the first step**, solar ultraviolet radiation breaks apart one oxygen molecule (O₂) to produce two highly reactive oxygen atoms (2O[•]) (Fig. 14.12).



- ii. **In the second step**, each of these highly reactive atoms combines with an oxygen molecule to produce an ozone molecule (O₃). These reactions occur continuously whenever ultraviolet radiation is present in the stratosphere. As a result, the largest ozone production occurs in the stratosphere region of the atmosphere.



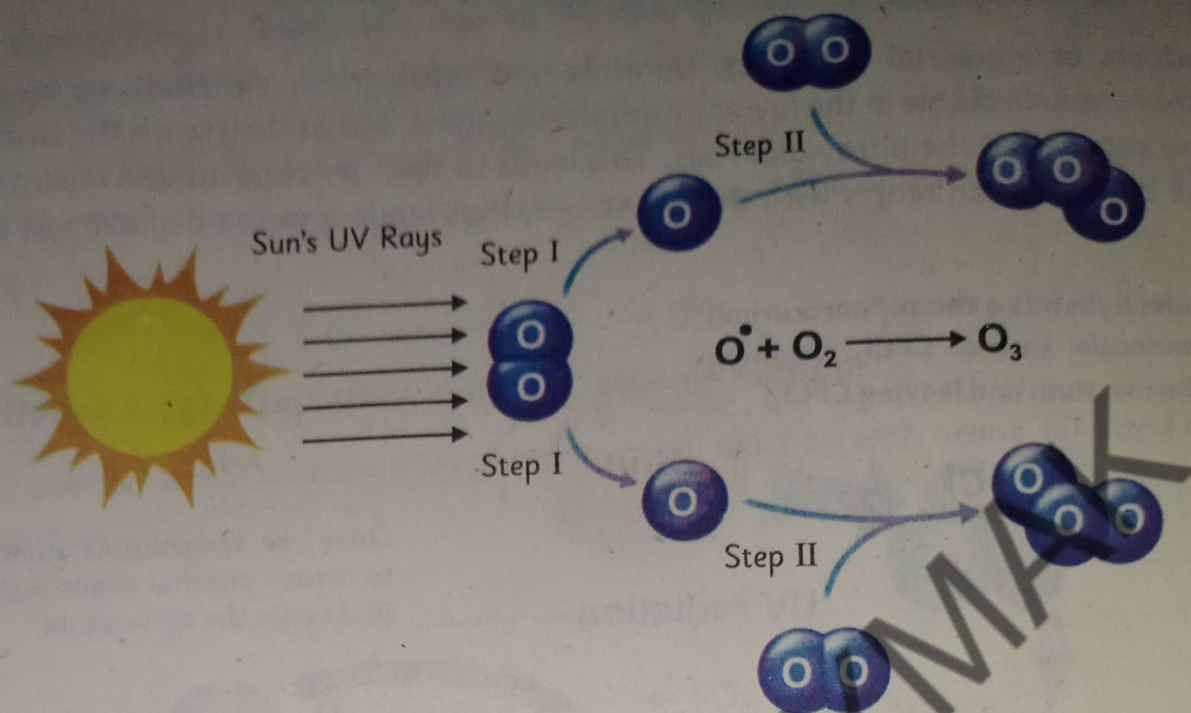


Fig.14.12 Ozone Formation

14.5.3 Ozone Layer Depletion

The layer of ozone gas protects us from the harmful ultraviolet radiations of the sun. The decrease in the concentration of ozone in stratosphere below its normal or natural level is termed as ozone depletion.

Ozone layer depletion refers to the thinning of the ozone layer, which allows more ultraviolet radiation to reach the earth's surface. The region in which ozone layer depletes is called **ozone hole**.

Tidbit

Lightning strikes produce O_3 , which is ozone, and strengthen the ozone layer of the atmosphere.

14.5.4 Causes of Ozone Layer Depletion

Things that lead to destruction of the ozone gas in the ozone layer depletion are the production and emission of chlorofluorocarbons (CFCs). This leads to almost 80 % of the total ozone layer depletion.

Beside this, many other substances, which lead to ozone layer depletion are hydro chlorofluorocarbons (HCFCs) and volatile organic compounds (VOCs). These substances are found in vehicular exhaust emissions,

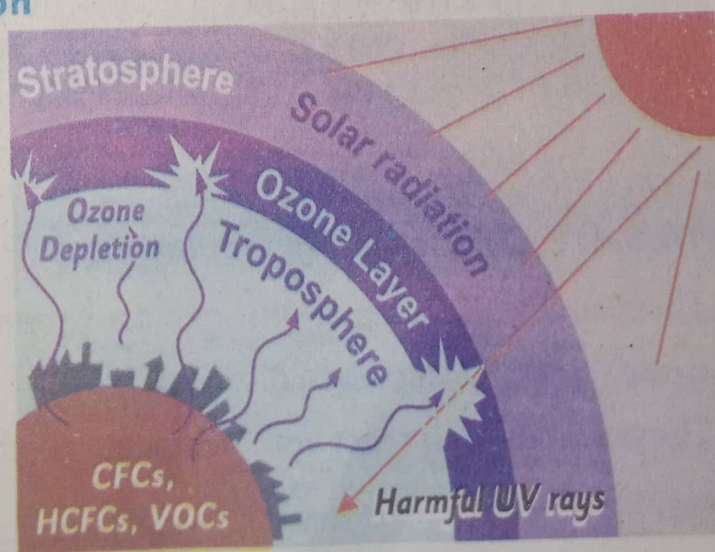


Fig.14.13 Ozone Layer Depletion

by-products of industrial processes, aerosols and refrigerants. All these ozone-depleting substances remain stable in the lower atmospheric region, but as they reach the stratosphere, they are exposed to the ultraviolet rays. This leads to their breakdown and releasing of free chlorine atoms, which reacts with the ozone gas, thus leading to the depletion of the ozone layer.

Ultraviolet light hits a chlorofluorocarbon (CFC) molecule, such as CFCl_3 , breaking off a chlorine atom and leaving CFCl_2 .

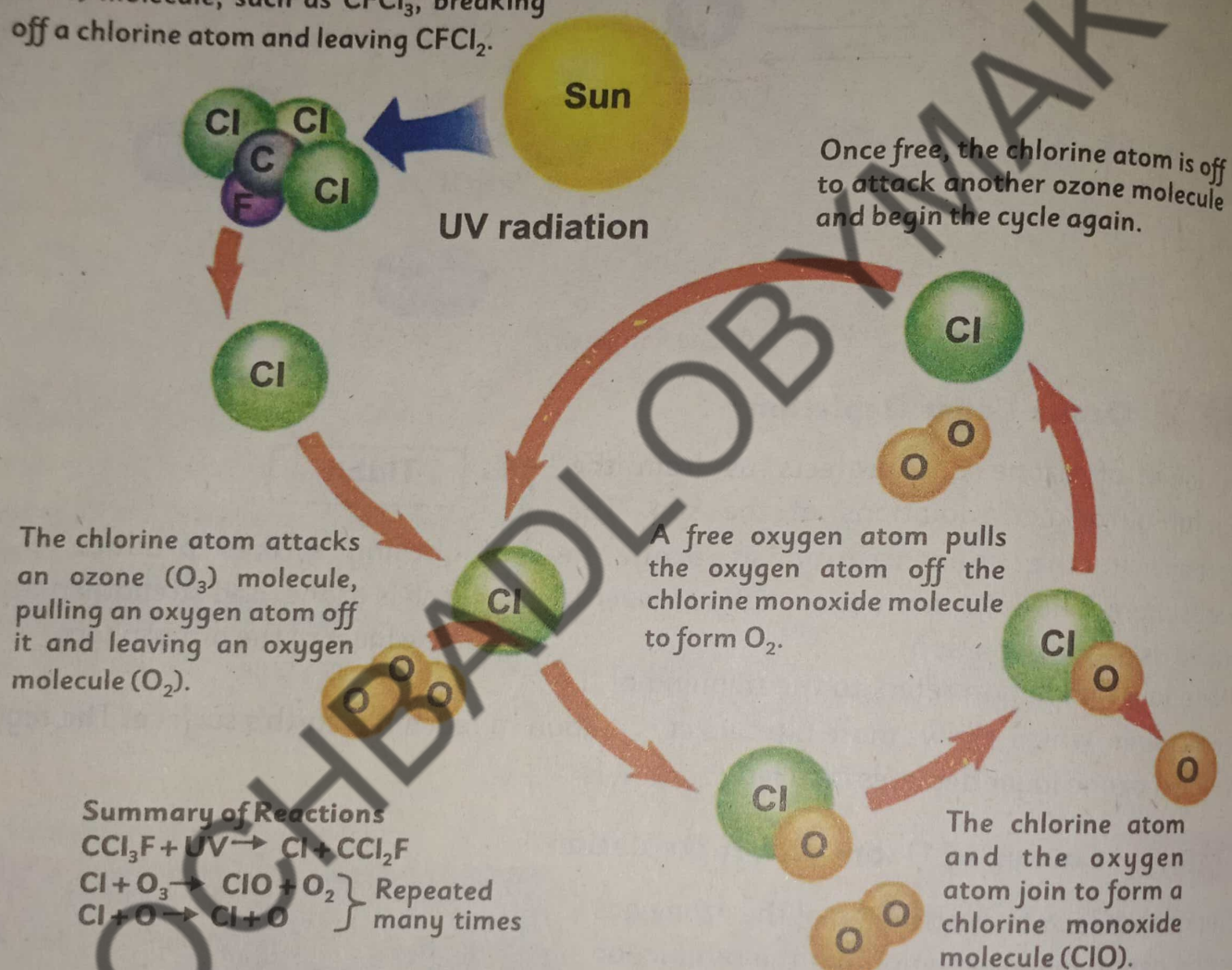
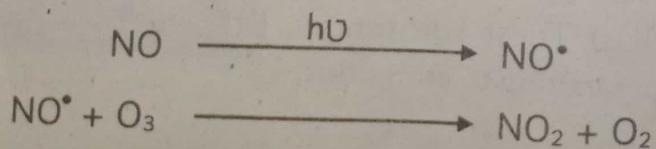


Fig.14.14 Ozone Depletion Reaction Mechanism

14.5.4.1 Ozone Layer Depletion due to NO_x

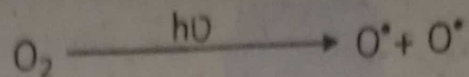
Three types of oxides of nitrogen are found in atmosphere i.e. NO (nitric oxide), N_2O (nitrous oxide), and NO_2 (nitrogen dioxide).

These oxides may react with ozone photo-chemically and cause its depletion.

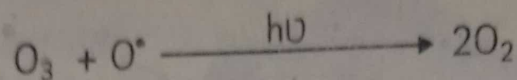


14.5.4.2 Ozone Layer Depletion due to Atomic (nascent) Oxygen

The atomic oxygen is produced by the following reaction.

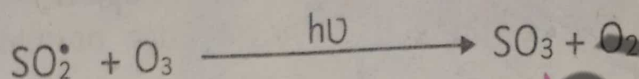
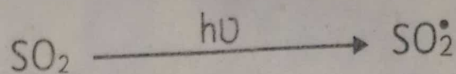


This atomic oxygen is very important and consumes about 18% of the ozone (O_3) found in atmosphere.



14.5.4.3 Ozone Layer Depletion due to Oxide of Sulphur

The sulphur dioxide gas (SO_2) undergoes photochemical reaction with ozone, (O_3) and causes its dissociation as,



14.5.5 Effects of Ozone Layer Depletion

The depletion of ozone layer allows the entering of ultraviolet radiations from the sun into the earth's atmosphere. This is associated with a number of health related and environmental issues. Some of its major impacts on living things are given below.



Fig.14.15 Exposure to Ultraviolet cause skin cancer

i. **Skin Cancer:** Exposure to Ultraviolet rays from sun leads to increased risk of several types of skin problems. In minor cases, it causes sun burn but in major cases damages the skin tissues and cause skin cancer.



Fig.14.16 Exposure to Ultraviolet cause cataract

ii. **Eye Damage:** Ultraviolet rays are harmful for our eyes. Direct exposure can lead to Cataract problems and other related problems.

iii. **Damage to Immune system:** Exposure to Ultraviolet rays can weaken the response of the immune system and even result in impairment of the immune system in extreme cases.

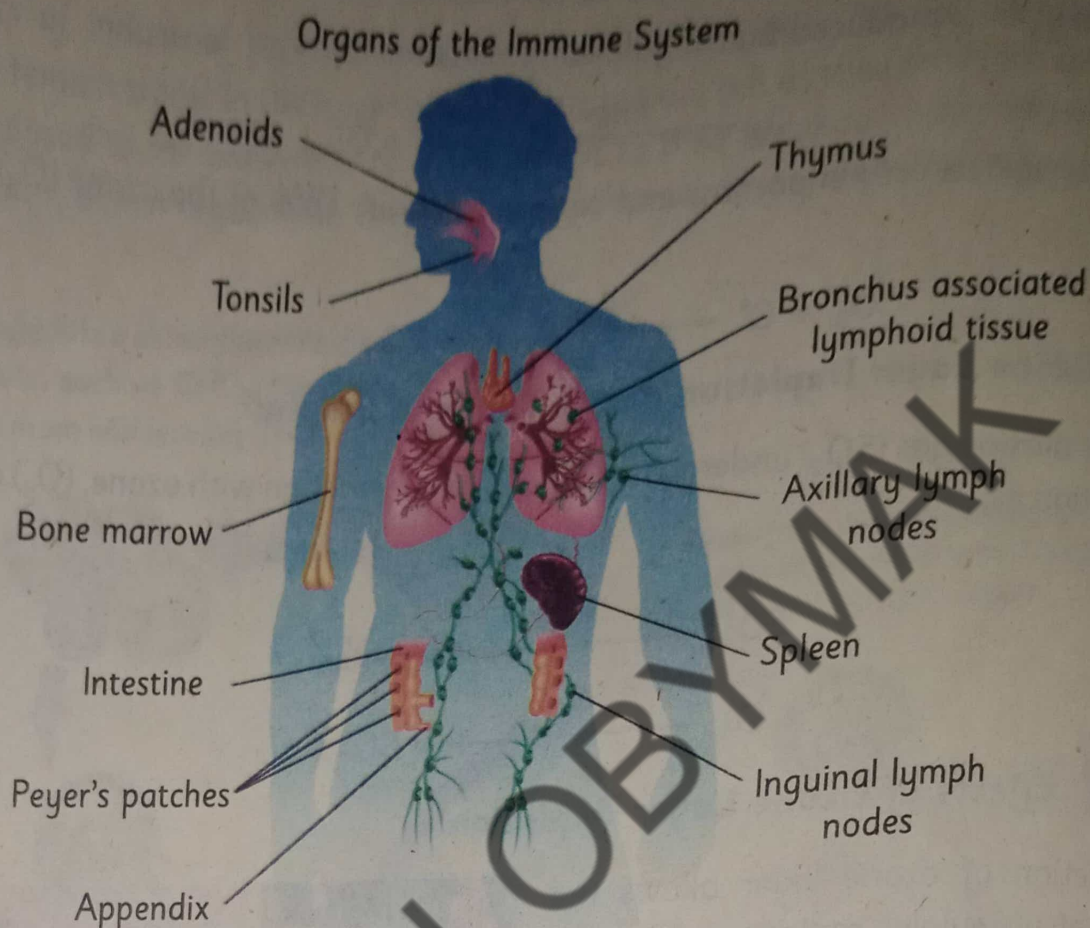


Fig.14.17 Exposure to Ultraviolet damage to immune system

iv. Aging of skin: Exposure to Ultraviolet rays accelerates the aging of our skin. As a result you will look older than your actual age.

v. Effect on amphibians: It adversely affects the different species of amphibians and is one of the major reasons for the decline in numbers of the amphibian species. It affects them in every stage of their life.

vi. Effect on marine life: Ultraviolet rays have adverse effect on the marine ecosystem.

These rays penetrate into water and kill the microorganisms. It also adversely affects the phytoplankton.

vii. Effect on plants: Ultraviolet rays also affect the plants by changing the physiological and development processes of the plants. They can also alter the time of flowering in some plant species.



Fig.14.18 Exposure to Ultraviolet radiation cause Aging of skin

- viii. **Effect on animals:** Ultraviolet rays cause serious problems for both humans and animals.
- ix. **Effect on material:** Exposure to ultraviolet radiation reduce the life span of different synthetic material like plastic, nylon etc.

14.5.6 Ways to Bring Down Ozone Layer Depletion

Ozone layer depletion is not something that affects any specific country or region. The whole world is exposed to its adverse effects, which makes it important for each and every one of us to take actions to reduce ozone layer depletion. Buying and using recycled products, saving of energy, using of public transport can do a lot in combating ozone layer depletion.

14.5.7 Global Warming

Global warming is the increase in average temperature of the earth's surface (both land and water) as well as its atmosphere.

Causes of Global Warming
Global warming is caused by increasing the concentration of green house gases which are mostly produced by human activities such as deforestation and burning of fossil fuels. Greenhouse gases include CO_2 , CH_4 , NO_2 , and O_3 . These gases act like a greenhouse around the earth. These gases allow the visible and ultraviolet rays from the sun to enter into atmosphere. But they do not allow the heat to escape back into the space. So this entrapped heat causes global warming.

The greenhouse effect is a naturally occurring process. Without the greenhouse effect, life on the earth would be probably not possible, as the average temperature of the earth would be about -18°C , rather than the present 15°C . The natural greenhouse effect, maintains the earth's temperature at a safe level making it possible for humans and many other life forms to exist.

However, the human activities have significantly enhanced the greenhouse effect causing the earth's average temperature to rise. This is the cause of global warming. Research has shown that average temperature has increased over the last few decades.

Effects of Global Warming
Global warming is affecting many places around the world. It is accelerating the melting of ice sheets, ice on hills and glaciers, which is causing an average rise in the sea levels. These changes have direct effect on both nature as well as humans. Thus, global warming is adversely affecting the climate, sea level, ozone layer, crop yield, precipitation (rain, and snow fall) and health.

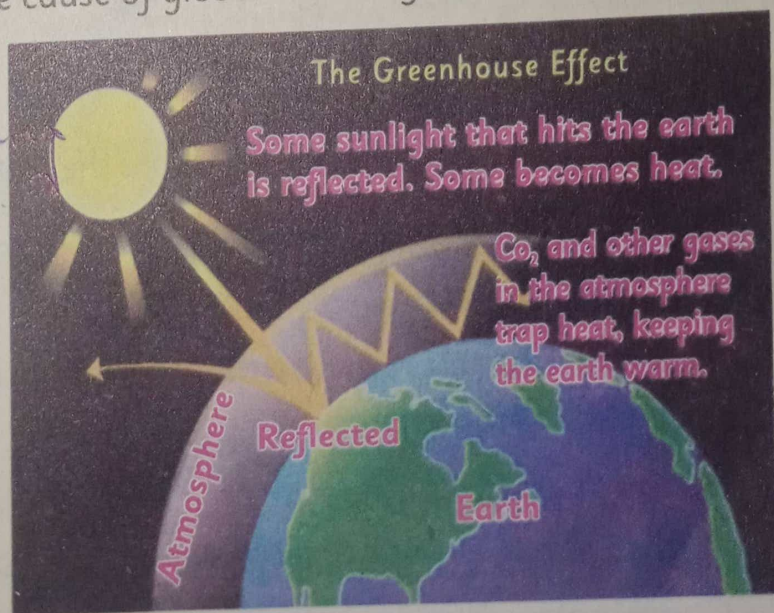


Fig.14.19 Greenhouse Effect

14.5.7.1 Effects of global warming

Global warming is damaging the Earth's climate as well as the physical environment. Global warming is harming the environment in several ways including:

- Desertification
- Increased melting of snow and ice
- Sea level rise
- Stronger hurricanes and cyclones

i. Desertification

Increase in temperature around the world changes the water cycle and rainfall pattern which causes desertification of certain areas.

ii. Increased melting of snow and ice

Snow and ice are melting at a faster pace due to the rise in temperature. More than 1 million square miles of sea ice has melted in recent few years.

iii. Sea level rise

Increase in average temperatures cause ocean waters to expand (thermal expansion) on one hand and accelerates the melting of ice and glaciers on another hand and thus raises the sea level.

iv. Stronger storms and cyclones

Global warming also increases the frequency of strong cyclones. Increase in the temperature above the sea surface results in the increase of frequency of storms.

Self Assessment

1. What is ozone? Explain ozone formation.
2. Discuss acid rain formation and its effects on materials.
3. What is ozone layer depletion? Explain the causes of ozone layer depletion.
4. Explain the effects of ozone layer depletion. How can we reduce the ozone layer depletion?
5. Define greenhouse effect.
6. Define global warming. What are the effects of global warming?

Activity 14.3

Perform filtration experiments in the lab on different water samples having suspended impurities

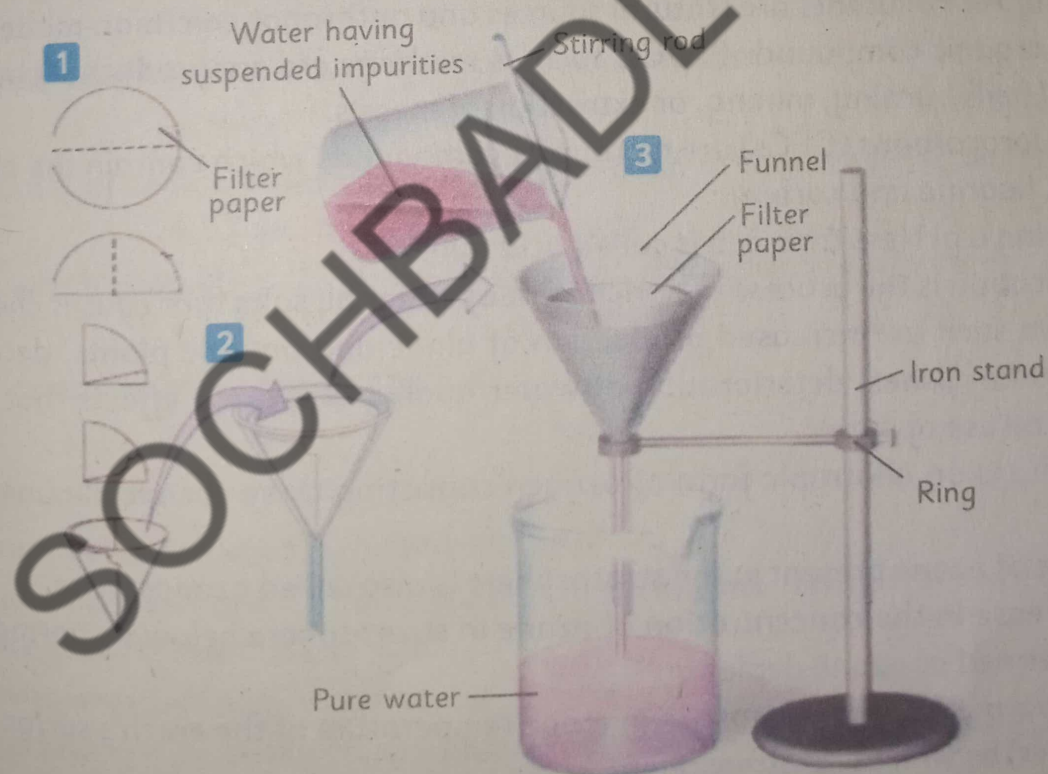
Apparatus and equipments

Beakers, filter papers, glass stirrer, iron stand

Chemicals: Alum (potassium aluminium sulphate powdered)

Procedure

1. Take water samples from different sources. Label these samples.
2. Record the appearance and smell of the water samples.
3. **Adding coagulants:** Coagulation is the process in which dirt and other suspended solid particles in water sample stuck together, so they can be removed from water. Alum works as coagulant. Add alum to the sample water. Slowly stir this mixture for 4 minutes.
4. **Sedimentation process:** Sedimentation is the process where gravity pulls particles of alum and sediment them to the bottom of the container. For sedimentation process to occur, you must leave the sample undisturbed for 20 minutes.
5. Record your observations at 5 minute intervals for a total of 20 minutes based on changes in the water's appearance.
6. Now perform the filtration process by setting the apparatus as shown in the figure. Recall your previous knowledge of filtration process.
7. Observe the sample water before and after filtration and compare the appearance and smell of the water.



Filtration of Different Water Samples Having Suspended Impurities

Key Points

- The thick blanket of air and gases around the earth which helps to sustain life is called atmosphere.
- Atmosphere is a mixture of different gases such as Nitrogen, Oxygen, Argon, Carbon dioxide, Hydrogen, Neon, Helium, including water vapours and dust particles.
- The atmosphere can be divided into the following four layers or zones; troposphere, stratosphere, mesosphere and thermosphere/ionosphere.
- Troposphere is the closest layer to the earth's surface.
- Stratosphere starts at the top of troposphere and extends from 11 km to 50km above the sea level.
- The atmosphere plays an important role by protecting life on earth from dangerous ultraviolet and cosmic radiations.
- The substances that are responsible for causing air pollution are called air pollutants.
- Air pollution is a change in the physical, chemical and biological characteristics of air that causes adverse effects on humans and other organisms.
- Air pollutants can be classified into two types, Primary and secondary pollutants.
- Sources of Air Pollutants are Natural sources and anthropogenic/man-made sources
- Volatile organic compounds (VOCs) such as methane etc are produced wherever there are fossil fuels burning, mining, or extraction of metals.
- Chlorofluorocarbons (CFCs) are a group of compounds which contain the elements like chlorine, fluorine and carbon.
- Rain having a pH less than 5.6 is called acid rain.
- Eutrophication is the process of enrichment of water by salts that causes changes to the ecosystem such as: increased production of algae and aquatic plants, decrease in the production of fishes, deterioration of water quality and other effects that reduce and prevent the use of water.
- Ozone (O_3) is an allotropic form of oxygen consisting three chemically bonded oxygen atoms.
- The layer of ozone present in the stratosphere is also called ozonosphere.
- The decrease in the concentration of ozone in stratosphere below its normal or natural level is termed as ozone depletion.
- Global warming is the increase in average temperature of the earth's surface (both land and water) as well as its atmosphere.

Exercise

A. Choose the Correct Option.

1. Ozone is present in
 a. Mesosphere b. Thermosphere c. Stratosphere d. Troposphere
2. All are air pollutants except,
 a. NO_2 b. N_2 c. SO_2 d. SO_3
3. Which one of the following is responsible for global warming?
 a. increase in concentration of N_2 b. increase in concentration of CO_2
 c. increase in concentration of O_2 d. increase in concentration of O_3
4. The pH of acid rain is less than
 a. 13.6 b. 10.6 c. 7.6 d. 5.6
5. The coldest region in the atmosphere is
 a. Troposphere b. Stratosphere c. Mesosphere d. Thermosphere
6. Ozone is formed in the presence of ultraviolet radiations from,
 a. O and O b. O_2 and O c. O_2 and O_2 d. O_2 and O_3
7. The gas(es) which is/are responsible for acid rain is/are
 a. SO_2 b. NO_2 c. CO_2 d. All, SO_2 , NO_2 and CO_2
8. On the basis of temperature variation, the number of atmospheric regions are
 a. Five b. Two c. Three d. Four
9. The gas which protects the earth surface from ultraviolet radiations is
 a. CO_2 b. N_2 c. O_3 d. O_2
10. Lowest temperature in troposphere is,
 a. 5°C b. -5°C c. 56°C d. -56°C

B. Short questions.

1. How ozone layer is depleted in the atmosphere?
2. Differentiate between primary and secondary pollutants. Write the name and sources of greenhouse gases to the atmosphere.
3. Define environmental chemistry and atmosphere.
4. Sketch and briefly discuss the composition of atmosphere, by mentioning the percentage of each component.
5. How the acid rain affect the building material or statues?

6. Increase in concentration of CO_2 cause greenhouse effect, justify it.
7. Briefly discuss how the acid rain affects the aquatic life.
8. List the sources which produce CO and CO_2 to the atmosphere.
9. What are the adverse effects of global warming?
10. What is the importance of ozone?

C. Long questions.

1. a). Sketch and identify the different layers of atmosphere.
b). Differentiate between stratosphere and troposphere.
2. a). Air is polluted in the big cities of Pakistan, justify the statement.
b). Enlist the main sources of air pollution.
c). Prove that the oxides of nitrogen and sulphur causes air pollution.
d). Enlist the effects of air pollution.
3. a). What would be the result if Rainwater is acidic?
b). What could be done to minimize the formation of acid rain?
c). Write down the effects of acid rain on,
(i). Humans (ii). Plants (iii). Soil (iv). Materials
4. a). Explain ozone layer depletion.
b). Where does ozone layer lie in the atmosphere?
c). What evidence can you find that depletion of ozone occurs in the atmosphere?
d). Recommend few ways to protect the ozone layer.
5. a). Summarize the components of stratosphere and troposphere.
b). Describe ozone formation.
c). Greenhouse effect is good or bad for us, explain.
d). Predict the outcomes of global warming.

Project

1. Drawing Model Making Competition

Theme of the competition: **The Green House Effect and Global Warming**

Every student of the class should prepare a drawing or model.

2. Design and conduct an environmental study to examine that how can we control the air pollution caused by the automobile exhaust emissions. Prepare a report explaining your results.

3. Watch the Documentaries

- a. Age of stupid
- b. The inconvenient truth
- c. Chasing ice