Chapter 5

Environmental Chemistry-1 The Atmosphere

Time Allocation

Teaching periods	= 10
Assessment period	= 02
Weightage	= 10%

MAJOR CONCEPTS:

5.1 Composition of Atmosphere
5.2 Layers of Atmosphere
5.3 Pollutants
5.4 Acid rain and its effects
5.5 Ozone depletion and its effects
5.6 Green house effect

STUDENTS LEARNING OUT COMES (SLO'S)

- Define atmosphere. (Remembering)
- Explain composition of atmosphere. (Understanding)
- Differentiate between stratosphere and troposphere (Analyzing)
- Summarize the components of stratosphere and troposphere (Understanding)
- Describe major air pollutants. (Understanding)
- Describe source and effects of air pollutants. (Understanding)
- Explain ozone formation (Understanding)
- Describe acid rain and its effects (Understanding)
- Describe the ozone depletion and its effects (Understanding)
- Describe global warming (Understanding)

Introduction:

The scientific study of chemical and biological events that occur in natural settings is known as environmental chemistry. It is the study of chemical species' origins, interactions, movement, impacts, and destinies in the air, soil, and water environments, as well as the impact of human and biological activities on these. Environmental chemistry is an interdisciplinary subject that encompasses atmospheric, water, and soil chemistry, as well as depending significantly on analytical chemistry and being linked to other fields of study.

A material or energy which is present in excess of the natural concentration and produce an adverse effect upon the environment is known as pollutant and the phenomena is known as pollution. This pollution creates harmful effects on atmosphere which we will discuss in detail in this chapter.

What is atmosphere?

The earth is surrounded by a layer of gases called the atmosphere. The atmosphere protects Earth like a big blanket of insulation. It absorbs the heat from the Sun and keeps the heat inside the atmosphere helping the Earth to stay warm. This big blanket also helps to form our weather patterns and climate. All of these things are important for life and the Earth's ecology. The atmosphere does not end at a specific place. The higher above the Earth something is, the thinner the atmosphere around it is. There is no clear border between the atmosphere and outer space.

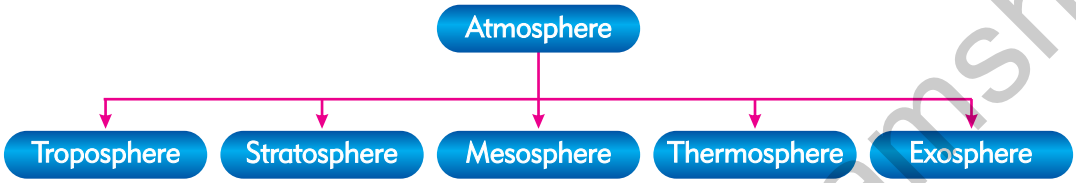
5.1 Composition of atmosphere

The atmosphere is the air that plants and animals breathe to survive. It is made up of nitrogen (78.09 %) and oxygen (20.95%), with small amounts of argon (0.93%), carbon dioxide (0.03 %), water vapor, and other gases. There are lots of other gases like neon, helium, hydrogen that are part of the atmosphere, but in much smaller amounts. Solid particulate, including ash, dust, volcanic ash, etc. are also small parts of atmosphere. They are important in making clouds and fog.

Figure 5.1 Composition of atmosphere

5.2 Layers of Atmosphere

The Earth's atmosphere is divided up into 5 major layers. These layers are classified on the bases of temperature and density with respect to earth surface; following are the layers of the atmosphere, starting from the ground to upward:



Here we will only discuss following two layers of atmosphere

Troposphere: The troposphere is the lowest layer of Earth's atmosphere. It extends from Earth's surface to an average height of about 12 km, although this altitude varies from about 9 to 17 kilometers (9 km at the poles, 17 km at the Equator) above earth's surface. This is where we live and even where planes fly mostly. Weather in this layer affects our daily life. Around 80% of the mass of the atmosphere is in the troposphere.

Stratosphere: The stratosphere is the second-lowest layer of Earth's atmosphere. It lies above the troposphere and is separated from it by the tropopause. This layer extends from the top of the troposphere at roughly 12 km above Earth's surface to the stratosphere at an altitude of about 50 to 55 km. The higher the altitude the hotter is the atmosphere. Unlike the troposphere the stratosphere gets its heat by the Ozone Layer absorbing radiation from the sun. As a result, it gets warmer the further away you get from the Earth. There are less water vapors and other substances in this layer. Weather balloons go as high as the stratosphere.

Figure 5.2 Earth atmosphere

Do You Know?

The higher you go in troposphere, the colder it is. Since At high altitude, atmospheric pressure is lower than that at sea level. It is this lower pressure at higher altitudes that causes the temperature to be colder on top of a mountain than at sea level.

Distinguish between Troposphere and Stratosphere

Troposphere	Stratosphere
1. It is the lowest point on the earth's surface.	1. It is the uppermost layer of the atmosphere after the troposphere.
2. It stands at a height of around 11 kilometers above sea level.	2. It rises up to 50 kilometers above sea level.
3. The troposphere makes up around 75% of the mass of the atmosphere.	3. The stratosphere has a far less amount of atmosphere than the troposphere.
4. As you climb higher in this sphere, the temperature drops steadily. It ranges in temperature from 15°C to -56°C.	4. The temperature fluctuates somewhat with height and usually the higher the altitude the hotter it gets.
5. Ozone, which is found here, is a polluting gas.	5. The presence of ozone here shields the planet from ultraviolet radiation.
6. There is a lot of movement of the air, and this area is part of an active weather system.	6. There is a lack of air movement in this area.
7. Almost all planes pass through this layer.	7. Airplanes are not permitted in this layer.
8. N_2, O_2, CO_2, and water vapours are the most essential gases in this sphere.	8. In this layer water vapours and gases are quite low in quantity.

Test Yourself

- What Is Atmosphere?
- From which gases our atmosphere is made up of?
- How would you differentiate between stratosphere and troposphere?

5.3 Pollutants

A waste material that pollutes the air, water, or land is referred to as a pollutant. A pollutant's severity is determined by three factors: its chemical type, concentration, and persistence. Human activities produce and release these contaminants into the environment. They endanger human life by polluting the environment (air, water, and

soil). Pollutants are chemicals that pollute the environment. Contaminants, on the other hand, are things that make something impure. Air pollutants are hazardous compounds found in the atmosphere. Pollutants in the air alter the weather, have a negative impact on human health, harm vegetation, and cause the destruction of structures.

Types of Pollutants

There are seven types of pollutants

- Air pollutants
- Water pollutants
- Soil pollutants
- Thermal pollutants
- Radioactive pollutants
- Noise pollutants
- Light pollutants

But in this chapter we will only discuss air pollutants and air pollution.

5.3.1 Major air pollutants

Primary and secondary pollutants are the two types of major air pollutants. The waste or exhaust products produced by the burning of fossil fuels and organic materials are referred to as primary pollutants. Sulfur oxide (SO_2), carbon oxides (CO_2 and CO), nitrogen oxides (especially nitric oxide NO), hydrocarbons (CH_4), ammonia, and fluorine compounds are among them. Primary pollutants create secondary pollutants through a variety of processes. Sulphuric acid, carbonic acid, nitric acid, hydrofluoric acid, ozone, and peroxy acetyl nitrate (PAN) are secondary pollutants.

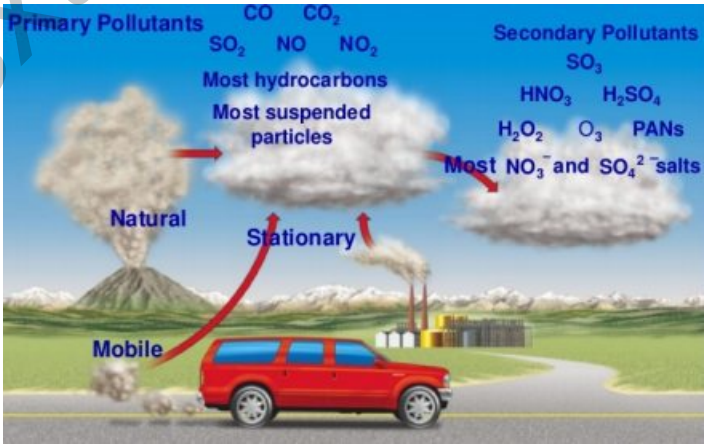
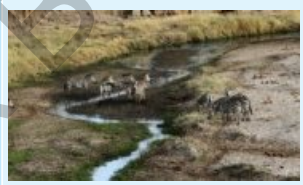


Figure 5.3 Major air pollutants

Pollutant	Sources	Environmental risks	Human health risks
Carbon monoxide (CO)	Emissions from automobiles, fires, and industrial operations	causes the production of smog 	In healthy persons, it can increase symptoms of cardiac disease, such as chest discomfort; it can also cause visual difficulties and diminish physical and mental skills.
Nitrogen oxides (NO and NO_2)	Emissions from automobiles, electrical generation, and industrial operations	It causes harm to the plants and helps to the creation of pollution. 	Inflammation and irritation of the respiratory tract.
Sulfur dioxide (SO_2)	Electricity generation, fossil-fuel burning, industrial activities, and automotive emissions are all examples of pollution sources.	Key contributor to the creation of acid rain, which destroys flora, buildings, and monuments; interacts to generate particulate matter 	Having trouble breathing, especially if you have asthma or heart problems
Ozone (O_3)	NOx and VOCs from industrial and car emissions, gasoline vapours, chemical solvents, and electrical utilities are all sources of ozone.	Interferes with certain plants' capacity to breathe, making them more vulnerable to other environmental stresses (e.g., disease, harsh weather) 	Lung function is impaired, and breathing passageways are irritated and inflamed.

Particulate matter	Fires, smokestacks, building sites, and unpaved roads are examples of primary particle sources; interactions between gaseous compounds released by power plants and cars are examples of secondary particle sources.	Contributes to the creation of haze and acid rain, which alters the pH balance of streams and harms vegetation, buildings, and monuments 	breathing passage discomfort, asthma exacerbation, irregular heartbeat
Lead (Pb)	Metal processing, garbage incineration, and fossil-fuel burning are all examples of industrial processes.	Biodiversity loss, reduced reproduction, and neurological difficulties in vertebrates are all issues that need to be addressed. 	When young children are exposed, it can have negative effects on numerous body systems and can lead to learning problems. Adults' cardiovascular consequences.

5.4 Acid rain and its effects

As you know, burning fossil fuels releases sulphur and nitrogen oxides into the atmosphere. SO_2 is converted to H_2SO_4 by rainwater, while NOx is converted to HNO_2 and HNO_3 by rainwater. Rainwater is somewhat acidic because it contains dissolved CO_2 from the atmosphere. It has a pH of 5.6 to 6. Rainwater, on the other hand, becomes increasingly acidic as a result of dissolving air pollutants (acids), and its pH drops to 4. Acid rain is created when rainwater dissolves acidic air pollutants like sulphur dioxide and nitrogen dioxide. The conversion of sulphur and nitrogen oxides into acids is seen in Figure. Acid rain causing harm to soil, animals, plants, and aquatic life.

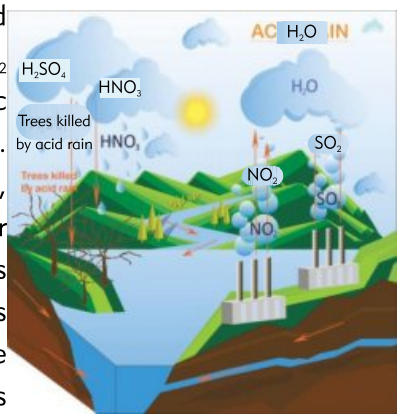


Figure 5.4
Acid rain

Effects of acid rain

1. Acid rain leaches heavy metals (Al, Hg, Pb, Cr, etc.) from soil and rocks and discharges them into rivers and lakes. Humans consume this water as a source of drinking water. These metals build up to hazardous levels in the human body. The aquatic life in lakes, on the other hand, suffers as a result of the high concentration of these metals. The fish gills become clogged when there is a very high concentration of aluminum ions. It causes fish to suffocate and die as a result.
2. Acid rain eats away the calcium carbonate in marble and limestone, which is found in many structures and monuments. As a result, these structures are becoming increasingly drab and degraded.
3. Acid rain makes the soil more acidic. Many crops and plants are unable to thrive in such conditions. It also raises the levels of hazardous metals in the soil, which damage the plants. Because of the acidity of the soil, even elderly trees are impacted. Their development is slowed. They wilt and perish as a result of the dryness.
4. Acid rain causes direct harm to tree and plant leaves, restricting their development. Plant development may be impeded depending on the severity of the injury. Plants' capacity to withstand cold or illnesses deteriorates, and they eventually perish.

5.5 Ozone Depletion and its Effects

Ozone Formation:

Three oxygen atoms make up ozone (O_3), a highly reactive gas. It is a natural and man-made substance that occurs in the higher atmosphere of the Earth (stratosphere).

Ozone has a positive or negative impact on life on Earth depending on its location in the atmosphere.

The interaction of solar ultraviolet (UV) light with molecular oxygen produces stratospheric ozone (O_3). The "ozone layer," which is located about 6 to 30 miles above the Earth's surface, decreases the quantity of dangerous UV light that reaches the earth surface.

Photochemical interactions between two primary groups of air pollutants, volatile organic compounds (VOC) and nitrogen oxides, produce tropospheric or ground-level ozone, in which humans breathe.

Ozone Depletion:

Three oxygen atoms make up ozone, which is an allotropic form of oxygen. It is created in the atmosphere when an oxygen atom joins an oxygen molecule in the mid-stratosphere.

Ozone is found in all parts of the atmosphere. However, its highest concentration, known as the ozone layer, is found in the stratosphere, roughly 25 to 30 kilometers above the Earth's surface. This layer surrounds the Earth and acts as a screen against damaging UV radiation. UV rays would induce skin cancer if ozone layer were not present. As a result, the ozone layer in the stratosphere is advantageous to life on earth.

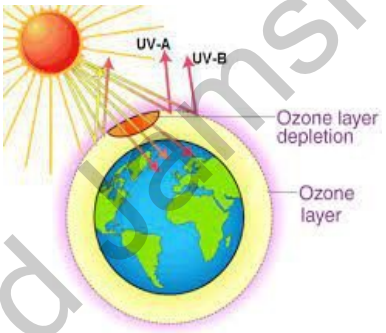


Figure 5.5
Ozone depletion

Ozone concentration in the stratosphere is essentially constant under normal conditions due to a series of complicated atmospheric interactions.

However, different chemical interactions are depleting the ozone layer. such as, chlorofluorocarbons (CFCs), which are utilized as refrigerants in air conditioners and refrigerators, are a major contributor to ozone depletion. These substances leak in some way and disperse into the stratosphere. The C-Cl bond in $CFCl_3$ is broken by ultraviolet light, resulting in chlorine free radicals.

These free radicals have a high level of reactivity. They react with ozone to produce oxygen in the following way:

$$O_{3(g)} + Cl^{\bullet} \longrightarrow O_{2(g)} + OCl^{\bullet}$$

$$OCl^{\bullet} \longrightarrow O^{\bullet} + Cl^{\bullet}$$

$$O^{\bullet} + O^{\bullet} \longrightarrow O_{2(g)}$$

A single chlorine free radical produced by the breakdown of CFCs has the potential to damage millions of ozone molecules. The ozone hole is a location where the ozone layer is depleted.

The first signs of ozone depletion were seen over Antarctica in the 1980s. Depletion has also been seen in the Arctic during the 1990s.

Effect of ozone depletion

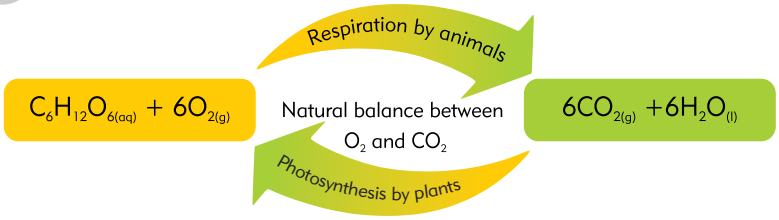
Even slight ozone depletion issues might have significant consequences.

1. Ozone depletion allows UV light from the Sun to reach the Earth, which can cause skin cancer in humans and other animals.
2. As the ozone layer gets thinner, infectious illnesses such as malaria become more prevalent.
3. It has the potential to disrupt the food chain by altering plant life cycles.
4. It has the ability to alter wind patterns, resulting in global climate shifts. Asia and the Pacific, in particular, would be the most impacted regions, as a result of the human migration issue caused by climate change.

5.6 Green House Effect (Global Warming)

CO_2 produces an envelope-like layer surrounding the Earth. It permits the Sun's heat rays to flow through it and reach the Earth's surface. These rays are reflected off the Earth's surface and return to the upper atmosphere. The normal CO_2 layer concentration maintains enough heat to keep the atmosphere warm. As a result, maintaining a normal CO_2 content is both required and advantageous for maintaining a comfortable temperature. The Earth would have been uninhabitable otherwise. Instead of the current average temperature of 15°C, the Earth's average temperature would be around -20°C. CO_2 is not a contaminant of the atmosphere. Rather, it is a necessary gas for plants, just as O_2 is for mammals. Photosynthesis consumes CO_2 and produces O_2 in plants.

Animals consume O_2 in their breathing and emit CO_2. As a result, a natural equilibrium between these important gases exists, as seen above. However, as a result of various human activities spewing more and more CO_2 into the air, this equilibrium is being disrupted.



Despite the fact that CO_2 is not a harmful gas, its rising concentration as a result of the combustion of fossil fuels in various human activities is concerning. CO_2 in the atmosphere works as a greenhouse's glass wall. It permits UV and IR radiations to pass

through, but not the other way around. Some of the infrared light released by the Earth is trapped by it.

As a result, higher CO_2 concentration absorbs infrared radiation generated by the Earth's surface, preventing heat energy from exiting the atmosphere. It aids in preventing the surface from cooling down at night. As CO_2 concentrations in the atmosphere rises, less thermal energy is lost from the Earth's surface. As a result, the surface's average temperature progressively rises. This is known as the greenhouse effect. The quantity of CO_2 in the air has a direct relationship with this impact. The greater the amount of CO_2, the greater the heat trapping or warming. This phenomena is also known as global warming because of the increased temperature. Primary green house gases in the earth's atmosphere are, water vapors, CO_2, CH_4, N_2O and ozone.

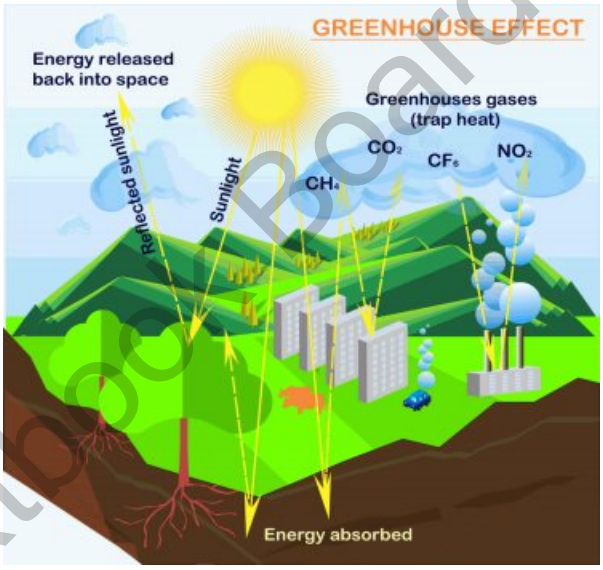
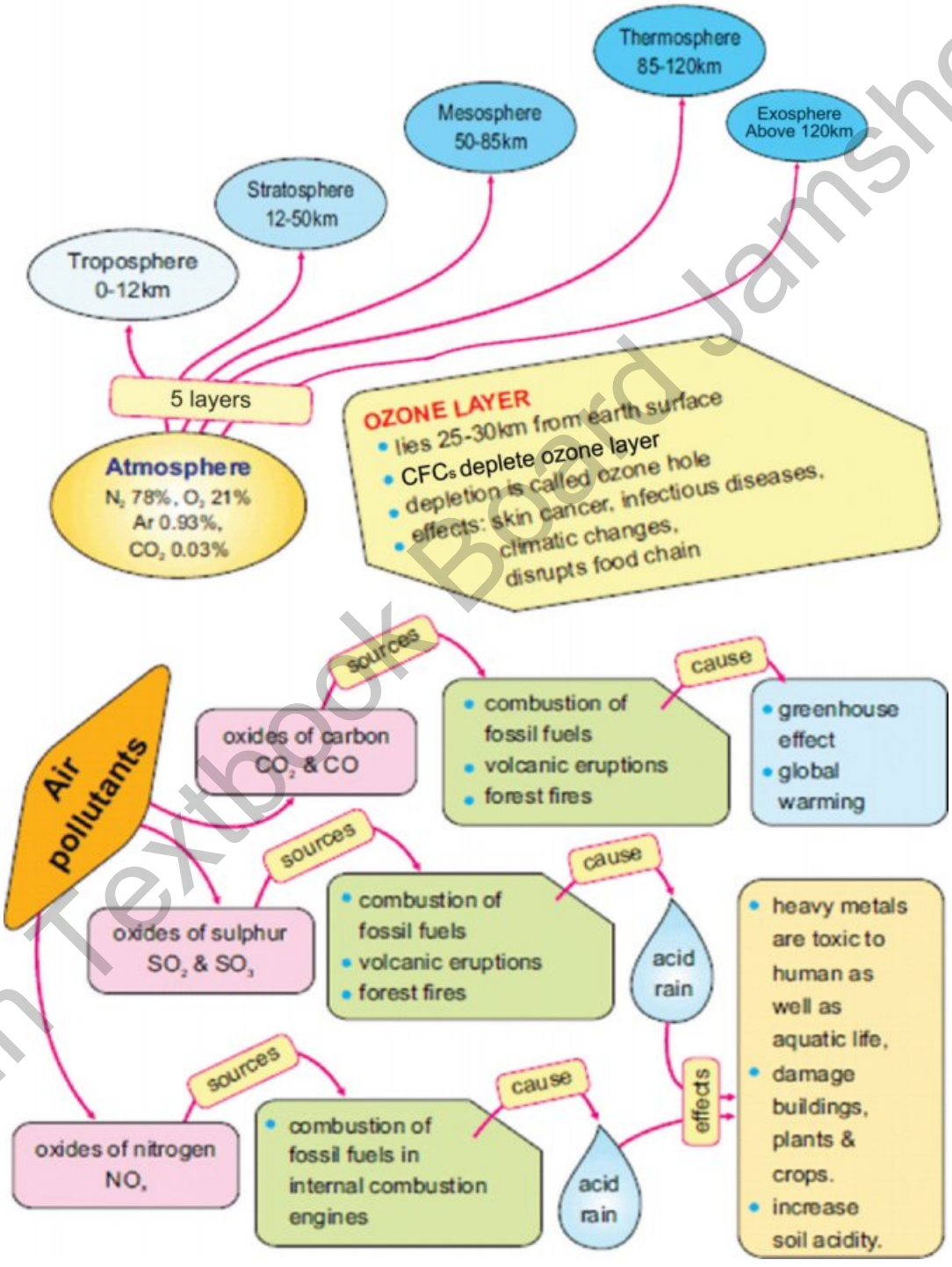


Figure 5.6 Green house effect

Effect of Global Warming

1. The accumulation of carbon dioxide in the atmosphere causes an annual increase in atmospheric temperature of roughly 0.05 degrees Celsius.
2. It's producing significant shifts in weather patterns. Extreme weather events are occurring more frequently and with more intensity than in the past.
3. It melts glaciers and snow caps, increasing the danger of flooding and intensifying tropical cyclones.
4. As the sea level rises, low-lying regions are more likely to be submerged, rendering previously populous places uninhabitable.

CONCEPT DIAGRAM



Summary

- The earth is surrounded by a layer of gases called the atmosphere.
- The earth's atmosphere is made up of nitrogen (78.09%) and oxygen (20.95%), with small amounts of argon (0.93%), carbon dioxide (0.03%), water vapors, and other gases.
- The Earth's atmosphere is divided into 5 major layers, namely: Troposphere, Stratosphere, Mesosphere, Thermosphere and Exosphere.
- Air pollution occurs when harmful or excessive quantities of substances including gases, particulates, and biological molecules are introduced into Earth's atmosphere.
- Major air pollutants are Carbon monoxide, Nitrogen dioxide, sulfur dioxide, lead, particulate matter and greenhouse gases.
- Acid rain is the precipitation of acidic components, such as sulfuric or nitric acid that fall to the ground from the atmosphere in wet or dry forms.
- Ozone is a gas majorly found in the lower stratosphere consisting of three oxygen atoms: O_3
- The major causes of ozone depletion are CFC's.
- The greenhouse effect is a warming of Earth's surface and the air above it.

Exercise

SECTION- A: MULTIPLE CHOICE QUESTIONS

1. Second highest layer of Earth's atmosphere is
   (a). stratosphere (b). mesosphere (c). troposphere (d). thermosphere
2. Aeroplanes fly in:
   (a). Troposphere (b). Stratosphere (c). Mesosphere (d). Thermosphere
3. Atmospheric pressure decreases with the
   (a). increase in longitude (b). decrease in altitude
   (c). increase in altitude (d). increase in latitude
4. Layer of atmosphere which separates stratosphere and troposphere is known as
   (a). tropo-pause (b). mesopause (c). thermopause (d). stratopause
5. Ozone layer is part of
   (a). mesosphere (b). stratosphere (c). thermosphere (d). troposphere
6. Which is not part of greenhouse gases
   (a). carbon dioxide (b). methane (c). nitrous oxide (d). oxygen
7. Second most abundant constituent of dry air in terms of volume after nitrogen is
   (a). nitrogen (b). oxygen (c). carbon dioxide (d). helium
8. Which of the following is the reason of global warming
   (a) Presence of sulphite
   (b) Rise in CO_2 concentration.
   (c) Oxides of nitrogen
   (d) Formtion of ozone
9. The altitude on stratosphere is:
   (a). 40 to 45 km (b). 50 to 55 km (c). 60 to 65 km (d). 70 to 75 km
10. Ozone is a gas found in the _____ layer:
    (a) Troposphere
    (b) Mesosphere
    (c) Stratosphere
    (d) Exosphere

SECTION- B: SHORT QUESTIONS:

1. Enlist major air pollutants and their sources.
2. Describe the effects of some air pollutants on human health?
3. What is the cause of acid rain?
4. Justify that Green house effect leads to global warming.
5. List down the layers of atmosphere.
6. Write down the effects of acid rain.
7. Justify that change in altitude change the temperature of atmosphere
8. What are primary and secondary air pollutants.

SECTION- C: DETAILED QUESTIONS:

1. Define atmosphere and explain its composition.
2. Differentiate between stratosphere and troposphere.
3. Describe that how different air pollutants effects environment and human health.
4. Describe Global Warming.