Quadrant II – Notes

Programme: Bachelor of Science (S.Y. B.Sc.)

Subject: Industrial Chemistry

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Unit: I

Module Name: Air, Oxygen and Nitrogen Cycle

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Segments of Environment:

Introduction

- **Environment** is the sum total of everything that directly influences the animal's chances of survival or reproduction.
- The environment consists of four segments. These are

(1) **Atmosphere** (2) **Hydrosphere** (3) **Lithosphere** (4) **Biosphere**

1) Atmosphere

- The atmosphere is the protective thick gaseous mantle which surrounds the earth.
- It saves the earth from the hostile environment of outer space.
- It acts as a source for CO_2 for plant photosynthesis and O_2 for respiration.

Functions of Atmosphere

- It absorbs most of the cosmic rays from outer space and protects living things from their harmful effects.
- Maintains the heat balance of the earth.
- It absorbs IR radiations emitted by the sun and reemitted from the earth and thus controls the temperature of the earth.

Structure of Atmosphere:

- There are five concentric layers within the atmosphere, which are differentiated on the basis of temperature. These include the **Troposphere**, the **Stratosphere**, the **Mesosphere**, the **Thermosphere** and the **Exosphere**.

2) Hydrosphere

- Covers more than 75 percent of the earth's surface either as oceans (salt water) or as fresh water.
- It covers all types of water resources such as oceans, seas, rivers, lakes, streams, reservoirs, glaciers and ground waters.
- A planet's hydrosphere can be liquid, vapour, or ice.
- On Earth, **liquid water** exists on the surface in the form of *oceans, lakes* and *rivers* and also below ground—as *groundwater, wells* and *aquifers.*
- **Vapour** form of water is most visible as *clouds* and *fog.*
- *Glaciers, ice caps* and *icebergs* are the forms of **frozen** part of Hydrosphere**.**

3) Lithosphere

- The solid component of the Earth is called lithosphere, which includes mainly soil, earth, rocks, mountains etc.
- Mainly contains three layers- **Crust**, **Mantle** and outer and inner **Core**.
- The **Core** is the central fluid or vapourised sphere having diameter of about **2500 km** form the centre.
- The **Mantle** extends about **2900-3000 km** above the core and is in molten state.
- The outer-most solid zone of the earth known as **Crust**, is about **840 km** above the mantle. The surface of crust is covered with the soil.

4) Biosphere

- The biosphere refers to the domain of living organisms and their interactions with the environment (i.e. atmosphere, hydrosphere and lithosphere).
- Under natural circumstances, plants and animals influence each others' life directly or indirectly.
- Green plants, through photosynthesis accumulate oxygen in the atmosphere, animals inhale O_2 during respiration and give out CO_2 which is utilized by plants during starch formation.
- Thus the interactions among the organisms are

  (1) **Symbiotic**, and (2) **Antagonistic**

AIR

The gaseous mixture of troposphere is nothing but air.

Composition of Air

- The lowest atmosphere i.e. the troposphere contains about 70% mass of the atmosphere. It has mainly three categories of gaseous components viz. major, minor and trace.
- The present average composition of clean dry air is represented in Table.

Chemical reactions occurring in air due to sunlight

Earth's atmosphere contains many gases which are capable of undergoing photochemical changes under the influence of sunlight.

Reactions in Troposphere

- CO_2 and water vapour of tropospheric environment exert a strong influence on climatic conditions.
- About 50% of sun's radiant energy falls in the visible region. Since the temperature of the Earth's surface is nearly 280^{o}K, the energy it radiates back into the space lies mainly in the Infra red region.
- CO_2 and H_2O absorb a considerable portion of the outgoing radiation.
- After absorbing the radiation, CO_2 molecule gets charged into a vibrationally excited molecule.
- The excited CO_2 molecule may collide with another molecule converting the excess vibrational energy into heat.
- The temperature of the atmosphere rises by 20^{o}K.
- This effect of CO_2 in increasing the Earth's temperature is commonly referred to as **"Green House Effect"**.
- **Consequences of Green House effect include**: Melting of ice caps, floods in coastal areas as the sea level rises, rapid water evaporation resulting in increased concentration of water vapour in the atmosphere.

Reactions in Stratosphere

- The major difference in the troposphere and the stratosphere air is that, the concentration of ozone is 10 ppm in stratosphere whereas it is 0.05 ppm inn troposphere.
- Ozone is formed in the Stratosphere by a photochemical reaction of Oxygen as,

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

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

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

- Ozone so formed, undergoes photodissociation in the following manner

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

- There exists a dynamic equilibrium in formation and decomposition of ozone molecules
- The heat generated during the reaction increases the stratospheric temperature while the Photochemical process absorbs most of the harmful radiations

Reactions in Mesosphere and Ionosphere

- Ionic species, such as O_2^+, O^+ and NO^+, which produced by sun's ultra violet radiation by photo-ionisation.
- The species so produced undergo ion molecule reactions as follows:

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

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

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

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

- Oxygen undergoes photolytic dissociation generating atomic oxygen.

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

- Some of these species exist in electronically excited state and their decay to the ground state causes "**auroras**" as observed in the northern hemisphere.

Oxygen

Oxygen in the troposphere plays an important role in the processes taking place on earth's Surface.

Reactions of Atmospheric Oxygen

1. Burning of Fossil fuels

$$CH_4 \text{ (in natural gas)} + 2O_2 \longrightarrow CO_2 + 2H_2O$$

2. Atmospheric oxygen is also used by aerobic organisms in the degradation of organic material or in oxidative weathering process.

$$HCHO + O_2 \longrightarrow CO_2 + H_2O$$

$$4FeO + O_2 \longrightarrow 2Fe_2O_3$$

3. The CO_2 and H_2O formed in the above reactions are utilized by the green plants in the process of photosynthesis and oxygen is again returned in the atmosphere.

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

Nitrogen cycle

Nitrogen cycle is a cycle in which atmospheric nitrogen is converted into its compounds such as nitrates and the combined nitrogen is again constantly passing back to the atmosphere.

Steps of Nitrogen cycle

1. Nitrogen Fixation
2. Nitrification
3. Assimilation
4. Ammonification
5. Denitrification

1. **Nitrogen Fixation**: Two types

a) **Biological N_2 Fixation:**

- This is done by symbiotic Nitrogen fixing bacteria such as Rhizobium present in the root nodules of legumes.
- Atmospheric nitrogen is fixed into its compounds which are easily taken up by plants.

b) **Non-biological N_2 Fixation**:

- Due to thunder storm, N_2 and O_2 combine to form NO which is oxidized to NO_2 which in turn combines with rain water to form nitric acid in the presence of O_2. nitric acid combines with basic substances in soil to form nitrates which is taken up by plants.

2. Nitrification

Nitrifying bacteria converts ammonia to nitrates.

3. Assimilation

Plants take N_2 from soil as amino acids, nitrate ions, nitrite ions, ammonium ions by absorption through their roots .

4. Ammonification

Excess of amino acids are converted into ammonium compounds such as ammonia, urea and uric acid by microorganisms in the soil through the process of ammonification.

5. Denitrification

- Reduction of nitrates back into inert Nitrogen gas.
- This completes the Nitrogen cycle.
- Denitrification takes place in anaerobic conditions.