Unit 13: Chemistry of air pollution -2025

Acid rain

Rain is one component of the water cycle. From the vapourization of water from various sources of water in the Earth's surface water enters the atmosphere. The condensation of this gaseous water due to various factors in the atmosphere and returning back to the surface of the Earth is called precipitation. There are several forms of precipitation. Rain is return as liquid water. Return in solid form occurs as snow and hails. In addition restoration also occurs by condensation into tiny droplets (aerosol) resulting in mist and fogs. Whatever is the way of return, the water coming back to the Earth from the atmosphere is the purest part of the hydrologic cycle.

That is because when atmospheric carbon dioxide dissolves in water, it combines with water to form a weak acid named carbonic acid.

Carbonic acid dissociates weakly and add H^+ ions to water.

Therefore pH of rain water is little less than the pH of neutral water.

That is, rain water is slightly acidic even in the absence of any other factor affecting it. This mild acidity is not harmful to aquatic organisms, man or any other water related activity.

But due to various natural and human activities more acidic gases are added to the atmosphere.

Ways of gaseous acidic oxides of nitrogen enter the atmosphere

Natural processes

During lightning where the temperature is high, atmospheric nitrogen reacts with atmospheric oxygen forming nitric oxide (NO) and nitrogen dioxide (NO_2).

NO and NO_2 are also produced by living in the environment. Gaseous acidic compounds of nitrogen are also produced by the oxidation of ammonia (NH_3) in the

The amount of acidic gaseous compounds released to the atmosphere by all these natural process is very small. Thus the composition of naturally produced acidic gases of nitrogen in the atmosphere is very small and has no significant effect on making rain water acidic.

Human activities

The main human activity that emits gaseous acidic compounds of nitrogen to the atmosphere

Ways of adding oxides of sulphur to the atmosphere

Natural ways

In the volcanic eruption, ash and gases containing huge amounts of sulphur dioxide are freed and these directly enter the atmosphere.

Oxidation of this gas in the atmosphere gives sulphur dioxide. However the sulphur dioxide concentration in the atmosphere remains at a very low level because sulphur dioxide produced as above spread across a

Acidic NO_X produced by human activities makes rain water acidic.

Ways of adding oxides of sulphur to the atmosphere

Natural ways

However the sulphur dioxide concentration in the atmosphere remains at a very low level because sulphur dioxide produced as above spread across a very large area of the atmosphere. Sulphur dioxide gas entering the atmosphere due to natural ways hardly contributes to make the rain water acidic. (Acid rains restricted to the relevant areas have been reported after volcanic eruptions.)

Human activities

How pH is lowered in rain water by acidic gases

NO is produced during the combustion in engines.

NO in vehicular emissions gets oxidized in the atmosphere giving NO_2.

In the presence of air NO_2 reacts with water and produce

SO_2 gas entering the air is further oxidized to SO_3 gas.

SO_3 reacts with water vapour to form sulphuric acid. In the presence of air SO_2 gas also reacts with water vapour giving sulphuric acid.

The compounds HNO_3 and H_2SO_4 formed above are strong acids. They completely ionize in water adding H_3O^+ ions to water in large amounts.

Because of the H_3O^+ ions added to water by the strong acids, the pH value of water decreases below the pH caused by carbonic acid formed by dissolving CO_2 gas.

Lowering of pH of rain water below 5.6 by adding strong acids to the rain is called acidification of water or formation of acid rain. High acidity of water leads to many problems.

Effects of the acidification of water

Aquatic organisms are very sensitive to the change of pH in water. Therefore even a small drop in pH in water is harmful to them. This causes changes in behavioural patterns, retardation of organogeny and destruction of eggs and immature organisms of fish and other aquatic organisms etc. This is detrimental to biodiversity.

Activities that could be taken to reduce acid rains

1.

Global warming

For all natural processes and dynamic activities carried out by man on the Earth, energy is provided by the sun. There is an empty space between the sun and all the other planets including the Earth. Because of this reason solar energy travels to the Earth as radiations.

Radiation energy of the sun reaching the Earth like this are subjected to

various transformations in the Earth finally leaves the Earth. That is to say, there is an energy equilibrium in the Earth.

Because of the transformations undergone by the radiant energy reaching the Earth heat is generated in the Earth. As a result the Earth gets heated up and reaches a certain temperature. Because of the transformation of solar energy, its return and establishment of an equilibrium, the extent to which the Earth is heated remains constant.

However due to Earth's 23.5^0 inclination to its axis's situation of latitude intensity of solar energy received by various regions is different. Because of this seasonal changes the temperature in different parts of the world in various time intervals is different.

For example, in equatorial regions the temperature is high and it is uniform throughout the year. From the equator to polar regions seasonality becomes acute and temperature within the year varies with in wide limits. The summer is extremely hot while the winter is intensely cold. In polar regions an extremely cold weather prevails throughout the year.

The average temperature of the Earth, that is 15 ^{0}C is a favorable condition for the existance of life. The reason for the prevalence of the favourabe temperature is the green house effect existing on the Earth. The potency of the green house effect on the Earth helps to maintain an optimum temperature favourable for life.

Greenhouse effect

As we all know, to grow an agricultural crop a certain optimum temperature is essential throughout the life of the crop. When we go from the equator of the Earth to mid latitude regions, the annual period of time with this optimum temperature gradually decreases. On reaching the polar regions, the time with optimal temperature necessary for plant growth becomes so short that plants do not grow in those regions. If plants grow at all, they are plants with a very short life span.

Hence, life in a particular region, if the time interval during which the optimum temperature necessary for a certain crop is less than its life span, growing that crop in the relevant, region is difficult. A greenhouse lengthens this period of optimal temperature without an external heat supply in a safe house located in that particular region. The temperature in a greenhouse is higher by 2 ^{0}C to 6 ^{0}C than the temperature outside. For this reason, even if the outer temperature is lower than the optimal temperature, it can be maintained that optimum temperature inside the greenhouse.

Action of a greenhouse

A greenhouse is an almost completely safe kept house. Its roof and walls are made of transparent material so that solar rays can penetrate them. Through these transparent materials visible and ultraviolet radiations coming from the sun, passes into the greenhouse.

Inside the greenhouse, these radiations are absorbed by the soil and other substances in it. The roofing materials and materials for the walls of the greenhouse are selected in such a way that they are transparent for the visible and UV radiations but reflect IR radiations.

This increases the temperature inside the greenhouse. This is the process takes place inside a green house. The atmosphere of the Earth too exhibits a process somewhat equal to the action of greenhouse. This is known as the greenhouse effect of the earth.

Greenhouse effect of the Earth

Solar radiations falling on the Earth are mainly belong to the ultraviolet and visible zones. Of these most of the radiations belonging to the ultraviolet zone are absorbed by the upper atmosphere and very little reaches the Earth's surface. It is UV radiations of very low energy that come like this. Visible rays and low energy UV rays reaching the Earth surface are absorbed by the Earth's surface (soil) and re-radiated as low energy radiations like in a greenhouse. In this re-radiation energy is emitted as low energy visible rays and IR rays. The emitted visible rays return to space without undergoing any significant change. But the IR radiations emitted could be absorbed by certain gases in the air. Fortunately the main gases in the air – N_2 (78%), O_2 (21%), Ar (1%), cannot absorb these IR radiations. If these gases occupying more than 99% of the Earth's atmosphere had absorbed IR radiations, the temperature of the Earth could have been very high.

Greenhouse gases

The gases which can absorb infrared radiations exist stably in the atmosphere for a long period of time are referred to as greenhouse gases.

Any gas having two or more atoms can absorb IR radiations. Also a hetero diatomic gases (e.g CO) can absorb IR radiations. Homo diatomic gases (N_2, O_2) and monatomic gases (e.g. Ar) cannot absorb IR rays. Hence any gas which is not monatomic and homo diatomic can absorb IR rays. Nevertheless, if a gas is to act as a greenhouse gas in the Earth's atmosphere, it should have following characteristics.

Although would be present in certain amounts in the atmosphere and they are capable of absorbing IR rays, the gases such as SO_2, NO_2, NO and CO are not reckoned as greenhouse gases. This is because their life span in the atmosphere is very short. Of the above greenhouse gases, all the gases except halogenated hydrocarbons exist in nature or short-lived are not considered greenhouse gases. As per the foregoing facts the main greenhouse gases present in the atmosphere are,

The greenhouse gases mentioned before absorb IR rays emitted from the Earth and retain them long in the Earth. Therefore the Earth gets heated. The result of this heating is the maintenance of the normal temperature of the earth at around 15 ^{0}C. Thus greenhouse effect is favourable factor essential to sustain life.

The percentages of greenhouse gases in the Earth are given in below**.** Amounts of greenhouse gases in the Earth

Greenhouse gas	Quantity
Water vapor (%)	0.001 – 0.5
Carbon dioxide (ppm)	415
Methane (ppb)	1745
Nitrous oxide (ppb)	315
Volatile halogenated hydrocarbons (CFC, HFC, HCFC) (ppt)	53.3

What would happen if the percentage of greenhouse gases in the Earth increases? The outcome is the production of more heat in the Earth due to absorption of more IR radiations by the increased amount of greenhouse gases. The heat so produced circulated longer in the Earth causing an increase in Earth's temperature. Along with the indindustries initiated by man with the industrial development the proportion of greenhouse gases is gradually increasing. It increased rapidly industrial revolution after the second world war.

Changes in the composition of greenhouse gases before the industrial revolution and at present.

Gas	Composition in 1750 (Volume percentage)	Present composition (Volume percentage)
CO_2	0.028	0.041
CH_4	0.00007	0.00018
N_2O	0.000027	0.0000314
Halogenated hydrocarbons	0	0.00000000533

From Table 1.6 it is clear that the amount of all greenhouse gases has drastically increased. Owing to the increase in greenhouse gases the temperature of the earth has increased by ℃

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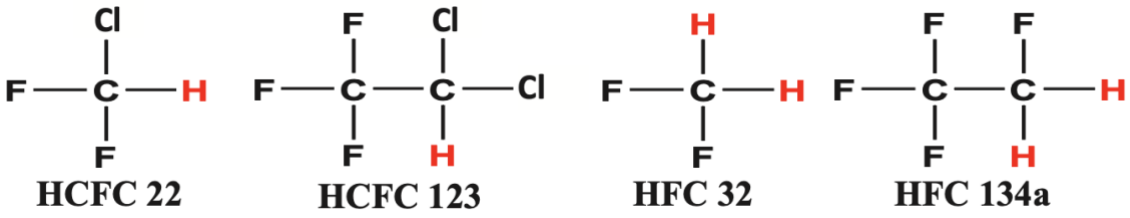
Human activities leading to the increase in greenhouse gas concentration Carbon dioxide (CO_2)

Methane

Nitrous oxide

Gaseous halogenated hydrocarbons

Halogenated hydrocarbons are very powerful greenhouse gases. These are ten thousand times as strong as carbon dioxide. For this reason, presence of these gases in the atmosphere even in small quantities contributes significantly to global warming. Halogenated hydrocarbons are rare in nature. Halogenated hydrocarbons responsible for increasing the global warming are,



All these three types are compounds synthesized by man and are used

Adverse effects of global warming

Global climate change

The following solutions could be suggested in this regard.