Composition and Structure of the Earth's Atmosphere

What is atmosphere?

We all know that earth is a unique planet due to the presence of life. The air is one among the necessary conditions for the existence of life on this planet. The air is a mixture of several gases and it encompasses the earth from all sides. The air surrounding the earth is called the atmosphere.

- Atmosphere is the air surrounding the earth.
- The atmosphere is a mixture of different gases. It contains life-giving gases like Oxygen for humans and animals and carbon dioxide for plants.
- It envelops the earth all round and is held in place by the gravity of the earth.
- It helps in stopping the ultraviolet rays harmful to the life and maintains the suitable temperature necessary for life.
- Generally, atmosphere extends up to about 1600 km from the earth's surface. However, 99 % of the total mass of the atmosphere is confined to the height of 32 km from the earth's surface.

Composition of the atmosphere

- The atmosphere is made up of different gases, water vapour and dust particles.
- The composition of the atmosphere is not static and it changes according to the time and place.

Gases of the atmosphere

Permanent Gases of the Atmosphere

Constituent	Percent by Volume	Concentration in Parts Per Million (PPM)
Nitrogen (N_2)	78.084	780,840.0
Oxygen (O_2)	20.946	209,460.0
Argon (Ar)	0.934	9,340.0
Carbon dioxide (CO_2)	0.036	360.0
Neon (Ne)	0.00182	18.2
Helium (He)	0.000524	5.24
Krypton (Kr)	0.000114	1.14
Hydrogen (H_2)	0.00005	0.5

- The atmosphere is a mixture of different types of gases.
- Nitrogen and oxygen are the two main gases in the atmosphere and 99 percentage of the atmosphere is made up of these two gases.
- Other gases like argon, carbon dioxide, neon, helium, hydrogen, etc. form the remaining part of the atmosphere.
- The portion of the gases changes in the higher layers of the atmosphere in such a way that oxygen will be almost negligible quantity at the heights of 120 km.
- Similarly, carbon dioxide (and water vapour) is found only up to 90 km from the surface of the earth.

CARBON DIOXIDE:

- Carbon dioxide is meteorologically a very important gas.
- It is transparent to the incoming solar radiation (insolation) but opaque to the outgoing terrestrial radiation.
- It absorbs a part of terrestrial radiation and reflects back some part of it towards the earth's surface.
- Carbon dioxide is largely responsible for the greenhouse effect.
- When the volume of other gases remains constant in the atmosphere, the volume of the carbon dioxide has been rising in the past few decades mainly because of the burning of fossil fuels. This rising volume of carbon dioxide is the main reason for global warming.

OZONE GAS:

- Ozone is another important component of the atmosphere found mainly between 10 and 50 km above the earth's surface.
- It acts as a filter and absorbs the ultra-violet rays radiating from the sun and prevents them from reaching the surface of the earth.
- The amount of ozone gas in the atmosphere is very little and is limited to the ozone layer found in the stratosphere.

Water Vapour

- Gases form of water present in the atmosphere is called water vapour.
- It is the source of all kinds of precipitation.
- The amount of water vapour decreases with altitude. It also decreases from the equator (or from the low latitudes) towards the poles (or towards the high latitudes).
- Its maximum amount in the atmosphere could be up to 4% which is found in the warm and wet regions.
- Water vapour reaches in the atmosphere through evaporation and transpiration. Evaporation takes place in the oceans, seas, rivers, ponds and lakes while transpiration takes place from the plants, trees and living beings.
- Water vapour absorbs part of the incoming solar radiation (insolation) from the sun and preserves the earth's radiated heat. It thus acts like a blanket allowing the earth neither to become too cold nor too hot.
- Water vapour also contributes to the stability and instability in the air.

Dust Particles

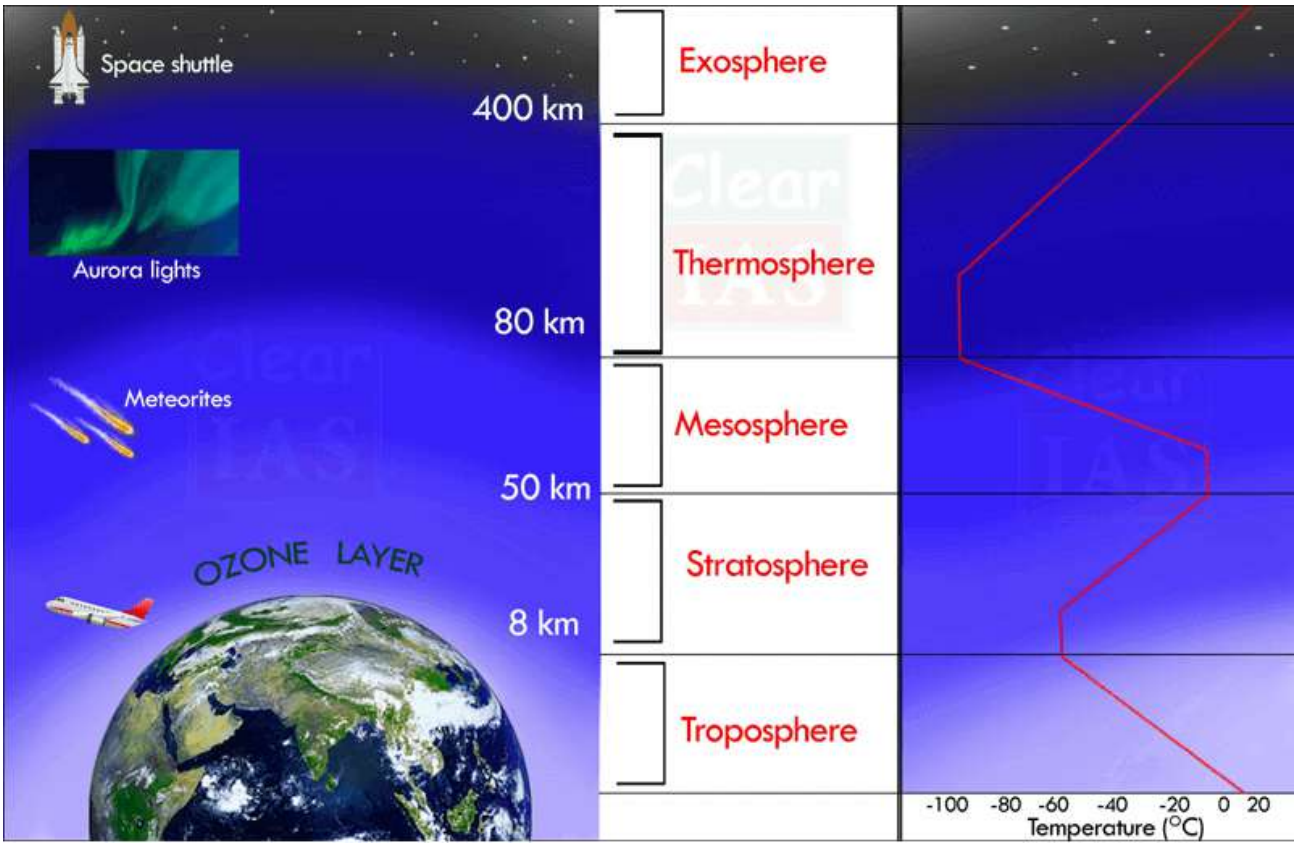
- Dust particles are generally found in the lower layers of the atmosphere.
- These particles are found in the form of sand, smoke-soot, oceanic salt, ash, pollen, etc.
- Higher concentration of dust particles is found in subtropical and temperate regions due to dry winds in comparison to equatorial and polar regions.

- These dust particles help in the condensation of water vapour. During the condensation, water vapour gets condensed in the form of droplets around these dust particles and thus clouds are formed.

Structure of the atmosphere

The atmosphere can be divided into five layers according to the diversity of temperature and density. They are:

1. Troposphere
2. Stratosphere
3. Mesosphere
4. Thermosphere (Ionosphere)
5. Exosphere



Troposphere

- It is the lowermost layer of the atmosphere.
- The height of this layer is about 18 km on the equator and 8 km on the poles.
- The thickness of the troposphere is greatest at the equator because heat us transported to great heights by strong convectional currents.
- Troposphere contains dust particles and water vapour.

- This is the most important layer of the atmosphere because all kinds of weather changes take place only in this layer.
- The air never remains static in this layer. Therefore this layer is called ‘changing sphere’ or troposphere.
- The environmental temperature decreases with increasing height of the atmosphere. It decreases at the rate of 1 degree Celsius for every 165 m of height. This is called Normal Lapse Rate.
- The zone separating troposphere from the stratosphere is known as tropopause.
- The air temperature at the tropopause is about – 80 degree Celsius over the equator and about – 45 degree Celsius over the poles. The temperature here is nearly constant, and hence, it is called tropopause.

Stratosphere

- Stratosphere is found just above the troposphere.
- It extends up to a height of 50 km.
- The temperature remains almost the same in the lower part of this layer up to the height of 20 km. After this, the temperature increases slowly with the increase in the height. The temperature increases due to the presence of ozone gas in the upper part of this layer.
- Weather related incidents do not take place in this layer. The air blows horizontally here. Therefore this layer is considered ideal for flying of aircraft.
- The upper limit of the stratosphere is known as stratopause.
- One important feature of stratosphere is that it contains a layer of ozone gas.
- The relative thickness of the ozone layer is measured in Dobson Units.
- It is mainly found in the lower portion of the stratosphere, from approximately 20 to 30 km above the earth’s surface.
- It contains a high concentration of ozone (O3) in relation to other parts of the atmosphere.
- It is the region of the stratosphere that absorbs most of the sun’s ultra-violet radiations.

Mesosphere

- It is the third layer of the atmosphere spreading over the stratosphere.
- It extends up to a height of 80 km.
- In this layer, the temperature starts decreasing with increasing altitude and reaches up to – 100 degree Celsius at the height of 80 km.
- Meteors or falling stars occur in this layer.
- The upper limit of the mesosphere is known as mesopause.

Thermosphere

- This layer is located between 80 and 400 km above the mesopause.
- It contains electrically charged particles known as ions, and hence, it is known as the **ionosphere**.
- Radio waves transmitted from the earth are reflected back to the earth by this layer and due to this, radio broadcasting has become possible.

- The temperature here starts increasing with heights.

Exosphere

- The exosphere is the uppermost layer of the atmosphere.
- Gases are very sparse in this sphere due to the lack of gravitational force. Therefore, the density of air is very less here.

- **Note # 1. The Atmosphere:**
- **The gaseous canopy that envelops the lithosphere and the hydrosphere is known as the atmosphere. It consists of a mixture of various gases and is believed to extend about 10,000 km above sea level. Held to the earth by gravitational attraction, the atmosphere has its maximum density at sea level and decreases rapidly upward.**
- **Recent observations show that about 97 per cent of the atmosphere is confined within 29 km of the earth's surface.**
- **Air is a mechanical mixture of gases, not a chemical compound. Of the many constituting gases, Nitrogen (N_2), Oxygen (O_2), Argon (Ar), and Carbon-dioxide (CO_2), account for nearly 99-98% of the air by volume. Observations made by rockets show that these gases are mixed in remarkably constant proportion up to an altitude of about 80 km. In addition to these gases, other gases, water vapour and aerosols are also present in the air.**
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Components	Symbols	Volume in Percentage
Nitrogen	N_2	78.08
Oxygen	O_2	20.94
Argon	Ar	0.93
Carbondioxide	CO_2	0.03 (very variable)
Neon	Ne	0.0018
Helium	He	0.0005
Ozone	O_3	0.00006
Hydrogen	H_2	0.00005
Krypton	trace	
Xenon	trace	
Methane	trace	

- **The atmosphere can be divided conveniently into a number of well-marked horizontal layers, mainly on the basis of temperature. From the earth's surface to an altitude of about 80 km the chemical composition of the atmosphere remains highly uniform throughout, in terms of the proportions of its constituent gases.**
- **The name homosphere has been applied to this lower, uniform layer. The upper atmospheric layer varies significantly in its proportion of gases, so the name hetero-sphere has been given to that layer.**

  The homosphere is sub-divided into two important sub-layers:
- **(a) Troposphere:**
- **The lowest layer of the atmosphere is known as the troposphere. It is very important. All possible weather phenomena and atmospheric turbulence take place within this layer. Troposphere contains about 75 per cent of the total molecular or gaseous mass of the atmosphere and virtually all the water vapour and aerosols.**
- **Throughout this layer a general decrease of temperature is well-marked. Temperature decreases at a mean rate of 6.5°C/km or 3.6°F/1,000 feet. The whole zone is capped in most places by a temperature inversion level and in others by a zone which is isothermal with height.**

- **The troposphere thus acts as a lid which effectively limits convection. This inversion level or weather ceiling is called the tropopause. The height of the tropopause does not remain constant; it varies significantly either in space or time. The height is supposed to be correlated with a sea-level temperature and pressure.**
- **The latitudinal variation of tropopause in its altitude is also distinctive. At the equator this lies at an altitude of about 16 km because of great heating and vertical convective turbulence, while at the poles it lies at an altitude of only 8 km or 5 miles.**
- **(b) Stratosphere:**
- **Next to the troposphere lies the stratosphere, second important layer of the atmosphere. This layer extends upwards from the tropopause to about 50 km. It is important to note that the stratosphere contains much of the total atmospheric ozone, that reflects the harmful X-rays, gamma rays, etc. back to the upper layers of the atmosphere. The maximum temperature occurs at the stratopause, where the temperature may exceed 0°C.**

- **In the stratosphere, the density of air becomes very low and even limited absorption produces a large temperature increase. In summer, the temperatures increase fairly generally with height and the temperature is the lowest at the equatorial tropopause.**
- **In winter, the structure becomes rather complex with very low temperatures averaging -80°C at the equatorial tropopause. Similar low temperatures are observed in the middle stratosphere at high latitudes.**
- **The climatic events in the stratosphere are linked with the temperature and circulation changes in the troposphere. Any interaction between these two successive layers are likely to be highly complex and is a major topic of current meteorological research.**
- **The Upper Atmosphere:**
- **(a) Ozonosphere:**

  This layer has got its name from the fact that there is a maximum concentration of ozone between 30 to 60 km above the surface of the earth. The scientists are of the opinion that the presence of the ozone layer is a boon for the survival of life; it protects us from sunburn by absorbing the larger percentage of the ultraviolet radiation.

  The environmentalists have cautioned us about the gradual deterioration of ozone layer recently because of the emission of nitrogen oxides by supersonic air planes which may cause a serious biological damage to man, animal and plant life. Some scientists believe that ozonosphere is actually the upper part of the stratosphere.

  (b) Ionosphere:

  According to Pettersson, ionosphere lies beyond the ozonosphere at a height of about 60 km above the surface of the earth. The ionization of the atmosphere begins to occur at this level. This layer is important because it reflects back the radio waves for global radio transmission.

  The ionosphere is supposed to start at an altitude of 80 km above the surface.The layer lying between 50 and 80 km is called the mesopause. The temperature decreases with altitude in this layer. The upper boundary of the mesosphere is known as mesopause.

  (c) Exosphere:

  The outermost layer of the earth's atmosphere is known as the exosphere. It lies between 400 and 1,000 km. Here, air density is extremely low and hydrogen and helium gases predominate.

Note # 2. The Hydrosphere:

The hydrosphere, or water sphere, mostly covers the depressions of the lithosphere. Some amount of water is also found in the rocks and much exists in the form of water vapour in the atmosphere. The oceans represent about 71 per cent of the globe and therefore contain the great bulk of the water. The average depth of the oceans is about 3,800 m.

The total volume of the world oceans is about 1-4 billion cu. km. which comprises more than 97 per cent of the world's free water. Of the remaining 3 per cent, about 2 per cent is locked up in the ice sheets of Arctic and Antarctica and about 1 per cent is being represented by fresh water of the lands.

Sea or ocean water is a solution of salt whose constituents have maintained more or less fixed proportions over a considerable span of geologic time. In addition to their importance in the chemical environment of marine life, these salts make up a vast store-house of mineral matter.

The following tables shows the composition of sea water:

Composition of Sea Water

Name of salt	*Chemical formula*	*Gram of salt* (per 1,000 gram of water)
Sodium Chloride	NaCl	23
Magnesium Chloride	$MgCl_2$	5
Sodium Sulphate	Na_2SO_4	4
Calcium Chloride	$CaCl_2$	1
Potassium Chloride	KCl	0·7
Other minor ingredients	—	0·8
Total		34·5

- **The earth's water moves through an interesting cycle known as hydrological cycle. It is made up of two parts. In the first of atmospheric part, the horizontal movement of water vapour predominates. In the terrestrial, the second part, the movement of water in the liquid and solid phase predominates.**

  By evaporation, water enters the air as water vapour from the oceans and other water-bodies as also from plants and animals by transpiration. As the water vapour moves up the air it condenses and ultimately returns to the surface as precipitation.

- **From the land it returns back to the oceans or adds directly to the air through evaporation and transpiration. This functional interrelation of hydrosphere, atmosphere and lithosphere makes possible the continued existence of plant and animal life.**

- **Note # 3. The Lithosphere:**
- **The lithosphere is the upper rigid shell of the earth and is distinctly sub-divided into three layers. They are: the central one, or the core; the intermediate layer called the mantle; and the outer layer known as the earth's crust. Seismic studies have made it possible to distinguish the solid part of the earth into such distinctive layers or zones.**
- **Core:**
- **The core or the centrosphere is the inner and the densest layer of the earth. Seismic data reveals the fact that the outer core is in a liquid-like state. The temperature here, presumably, reaches a maximum of about 2,500 – 3,000°C on the border separating the mantle from the core. The density of the core is about 13 gram per cubic centimetre.**
- **It is evident from the seismic studies that the constituting substance of the core remains apparently in a solid state. One can readily assume that at such high values of pressure there occurs the destruction of substance which, in the inner core, exists in a metalized state or plasma.**
- **So far as the chemical composition of the outer and inner core is concerned, it remains more or less the same for the both sub-layers. The layer is called 'Nife' because of the pre-dominancy of Nickel (Ni) and Iron (Fe) as major constituents.**
- **Mantle:**
- **The mantle is the largest intermediate layer of the earth and is confined between the crust and the core. It is distinctly separated by the Mohorovicic discontinuity from above and the Weichert-Gutenberg discontinuity from the bottom. The mantle comprises of nearly of the earth's mass. So far only hypothetical assumptions are available regarding the composition of the mantle.**
- **The upper mantle is characterized by the presence of vertical and horizontal heterogeneities while the lower mantle and the intermediate layers are far more homogeneous. The upper mantle is primarily composed of iron and magnesium silicates, such as olivine, pyroxenes**

and garnets. The lower mantle, presumably, wholly consists of dense varieties, mineral oxides with the pre-dominancy of SiO_2.

- **Geophysical data prove that within the confinement of the mantle, solid state of matter predominates. The temperature reaches about 1,000°C on the border between the crust and mantle. The average density of the constituents is 5 to 6 times greater than the water and is about 2,895 km. thick.**

  Crust:

  The earth's crust is the upper solid part of the earth consisting of magmatic, metamorphic and sedimentary rocks with the thickness that varies between 7 to 70-80 km. The crustal layer represents the most active layer of the solid earth —the sphere of activity of all geologic processes.

  It was believed, until recently, that the earth's outer crystal layer was composed of lighter rocks known as SIAL (Si—Silica, Al—Aluminium.) which floated on a sea of heavier rocks known as SIMA (Si—Silica, Ma —Magnesium). But, recent investigations have revealed that large areas of the outer crystal layer are made of basaltic rocks, similar in composition to the Sima.

  The earth's crust is now regarded as a series of plates, some of which are being carried on by the Sial rocks. The crust of the continental type consists of three layers: they are the sedimentary, granitic and basaltic ones. The oceanic crust differs from the continental

variety in that its thickness is considerably smaller.

Layers of the Solid Earth and Their Characteristic Features (The Gutenberg-Bullen discontinuity)			
Geosphere	Depth interval in km.	Density interval g/cm^3	Volume (share of %)
Earth's crust	0-33	2·7-3·0	1·55
	Mohorovicic Discontinuity		
Mantle			
Outer mantle	33-410	3·32-3·65	16·67
Transit layer	410-1,000	3·65-4·38	21·31
Lower mantle	1,000-2,900	4·68-5·69	44·28
	Weichert-Gubenberg Discontinuity		
Core			
Outer core	2,900-4,980	9·4-11·5	15·16
Transitory zone	4,980-5,120	11·5-12·0	0·28
Inner core	5,120-6,370	12·0-12·3	0·76