AIR KNOWLEDGE

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Introduction

Air is everywhere even if we cannot see, taste or touch it. It does not have a smell of its own, but it is full of smells and scents that it carries to our noses: it is the air that allows us to smell the fragrance of flowers or the foul odour of car exhaust! Air enabled the development of life on Earth. It contains the oxygen needed for humans and animals to breathe and the carbon dioxide needed for plants to carry out photosynthesis. Air also enables the Earth to retain some of the heat from the Sun and repel the sun's harmful rays from living beings.

What is it

Air around us

The air we breathe consists of a mixture of gases and solid and liquid particles. Its composition is not constant, it can in fact vary from place to place and over time. Leaving aside the water vapour, atmospheric dust and other variable components, we find that the composition of the air is practically constant. Nitrogen and oxygen, equal to 78% and 20.95% by volume, respectively, are the two main components of the atmosphere. Nitrogen is a colourless and odourless gas and is inert, since it does not participate in vital processes, unlike oxygen, necessary for living beings to breathe. The oxygen in the air is almost entirely of biological origin, since it is produced by autotrophic organisms through photosynthesis.
The remaining 1% consists of:

- argon, equal to 0.93% by volume, an inert gas like nitrogen;
- carbon dioxide ($CO2$), equal to 0.03%, of natural and anthropogenic (i.e. generated by the activities carried out by man, such as combustion processes) origin, plays a key role in the greenhouse effect;
- other gases such as neon, krypton, xenon, hydrogen and others, which together make-up only 0.01% by volume of the atmosphere.

One of the most important components of the atmosphere is water vapour, which is the result of evaporation of the water of lakes, seas and rivers. In addition to being at the origin of clouds and precipitation, like carbon dioxide, water vapour has the ability to absorb the thermal energy radiated from the Earth. To learn more, visit the climate change section. The amount of water vapour present in the air can vary from almost zero up to a maximum of approx. 4% by volume.

Atmospheric dust

Atmospheric dust consists of microscopic solid and liquid particles present in small quantities and characterised by variable dimensions and physical and chemical characteristics. The dust may be of biological origin, such as pollen and spores, generally the result of biological processes, of geological origin (for example, the particulate coming from volcanic eruptions or erosion phenomena) or of human origin, such as the fine particles produced by the exhaust gases of cars. Atmospheric dust plays an important role in the process of cloud and fog formation since the surface of some of its particles promotes the condensation of water vapour. Moreover, dust can reflect solar radiation; in fact, when the atmosphere is particularly rich in dust, e.g. following a volcanic eruption, the solar radiation able to reach the Earth's surface is significantly reduced. Finally, the wide variety of colours and shades that characterise sunrises and sunsets is thanks to the dust.

Air for life

The atmosphere is an essential component for life on Earth, since it contains the oxygen that living organisms need to breathe. In addition, it filters out the harmful solar radiations, reflecting them and preventing them from reaching the soil, and allows the Earth's surface to maintain the right temperature for plants and animals to live. The atmosphere is also the place where the main weather phenomena (wind, rain, snow, etc.), that compose the climate, occur.

The respiration

The breathing process is the mechanism through which vegetables and animal organisms take the energy they need to perform their vital processes and grow. Breathing, which can be regarded as a low-temperature combustion, releases the energy contained in organic compounds that the organism takes in through food, by burning oxygen and releasing carbon dioxide and water. Essentially, whenever we breath in, the oxygen contained in the air reaches our lungs, gets into our blood, is carried to all the cells of our body and there it is used in the combustion processes that produce the energy required to keep us alive. The cells, in their turn, give back to the blood the by-products of combustion: carbon dioxide and water. These substances are carried by the blood to the lungs, which they leave as we breathe out.

The study of the atmosphere

The first scientific studies on the composition of the atmosphere started in the 18th century. The nature of air, infact, remained a mistery for a long time and only after 1770 Joseph Priestley (1733-1804), known for his pioneristic studies on the atmosphere, demonstrated that air contains something indispensable for the life of animals, oxygen, which will be defined with this word by Lavoisier some years after its discovery. Priestley also discovered that animals and humans "consume air" and that plants can renew and purify it. Priestley managed to demonstrate this with a peculiar experiment. He gathered breathed air (hence rich in $CO2$) and closed it hermetically in two containers, an empty one, and another one containing a plant. After

seven days, he introduced a small mouse in each container and he observed that the small mouse positioned in the container without the plant died before the other one positioned in the container with the plant.
The process responsible for these phenomena, photosynthesis, was discovered only one hundred years later, in 1862. As Priestley lived close to a brewery, moreover, he got interested in fermentation processes. He studied the characteristics of the gas released during these processes (which today is known as carbon dioxide) and, adding it to water, he invented sparkling water. The French chemist Antoine Lavoisier (1743-1794), father of modern chemistry, carried out important researches to understand the nature of combustion. With his experiments he demonstrated that combustion is a process that uses oxygen. The explanation of combustion given by Lavoisier replaced the phlogiston theory, which stated that materials that burn release a substance called phlogiston. He continued the studies started by Priestley also proving the role played by oxygen for animal and plant breathing as well as rusting of metals. He discovered, moreover, that hydrogen combines with oxygen to produce a dew that looked like water. Hydrogen had been discovered in 1766 by Henry Cavendish which obtained it from the reaction between metals and sulphuric acid and described it as “inflammable air coming from metals”. Antoine Lavoisier named it “hydrogenium”, which means “substance used to obtain water”, precisely after his discovery. In 1781 he discovered the formation reaction of carbon dioxide starting from carbon and oxygen.
Daniel Rutherford is considered the discoverer of nitrogen, even if this element had already been identified by Priestley, Scheele and Cavendish. Black, discoverer of fixed air (carbon dioxide) had observed that, when burning a “carbonaceous” substance in a closed container and absorbing carbon dioxide that developed within it with caustic soda (KOH), a gaseous residue (nitrogen) remained in the container. Rutherford, which studied this gas in 1772, noticed that it didn’t feed combustion and breathing but didn’t recognize it as a distinct chemical element and considered it as air saturated with phlogiston. It was Lavoisier who recognized that air is a combination of an active gas, oxygen, that feeds combustion and breathing, and an inactive gas, nitrogen.
The term “nitrogen” derived from the French azotè (an entry formulated by the same Lavoisier) that means “deprived of life” as this gas isn’t necessary for breathing. James Glaisher and Henry Tracey Coxwell in the 19th century risked their life venturing in the sky with an aerostatic balloon to explore the atmosphere. In this way they discovered that as the altitude rises, the air temperature diminishes and they made numerous measurements of humidity in the air. It has been estimated that their flights went beyond 9,500 metres over the sea level. At the end of the 19th and 20th century interest moved to the research of minor components of the atmosphere, existing in small concentrations. A particularly important discovery for atmospheric chemistry was the discovery of ozone made by chemist Christian Friedrich Schönbein in 1840. As he was making experiments on slow oxidation of white phosphor and electrolysis of water, Schönbein was the first to notice the characteristic smell of ozone that he associated to the smell of

atmospheric discharges of lightning during a storm. He coined the term “ozone” from the greek ozein, to smell. In the 20th century science of the atmosphere proceeded to the study of the composition of air and to the consideration of how concentrations of gases existing as traces in the atmosphere had modified over time and of chemical processes that create and destroy compounds in the air. Two particularly important examples of this were the explanation of how the ozonosphere forms and maintains itself by Sydney Chapman and Gordon Dobson and the explanation on smog by Haagen-Smit.

Atmosphere

The air completely surrounds the Earth and literally wraps it up in a shroud that, under the effect of gravity and centrifugal force caused by the Earth’s rotation, takes a spheroid shape (think of the shape of an egg), flatter at the poles and bulging at the Equator. This is why, even if its boundaries with the interplanetary spaces cannot be accurately identified, it has been called atmosphere (from the Greek *atmòs* = steam, and *sfaira* = sphere). A number of layers (spheres) can be identified in the atmosphere; these layers are concentric with the Earth and have different temperatures and chemical properties. Starting from the Earth’s surface (the soil) and going up, we find: the troposphere, the stratosphere, the mesosphere, the thermosphere and the exosphere.

Atmosphere layers

The troposphere. It is the first layer of the atmosphere, the one we live on. The heat that comes from the Earth’s surface warms this layer up and therefore the temperature diminishes when it goes upwards. In the troposphere the air always moves. The troposphere is characterized by atmospheric phenomena like the wind, cloud formation, precipitations, etc. Immediately above it, at a height that varies from the 8 km above the Poles and 18 km above the Equator, there is the tropopause, that represents that passage to the stratosphere.

The stratosphere. In this layer there is no phenomena determined by atmospheric turbulences, as it happens in all the next layers. Here the temperature increases as the height increases, since the ozone layer that is present in this area directly absorbs a part of solar radiations. The stratopause is the border with the mesosphere and it is located at 50 km of height.

The mesosphere. In this layer the temperature diminishes as the height increases. In fact the heat arrives from the Earth’s surface, which is quite far. At around 100 km of height, there is the thermal minimum temperature. The mesopause is located here, representing the passage to the thermosphere.

The thermosphere. The temperature in this layer increases as the height increases. The density of the gases diminished when they go up.

Exosphere. This is the most external layer of the atmosphere. It is also the least known. Researches have calculated that its temperature even exceeds 2000 °C.

Origin of the atmosphere

The atmosphere surrounding the Earth is very different from the atmosphere on our planet when it was created, 4.5 billion years ago. The origin of the present atmosphere, as well as that of other planets' atmospheres, is still widely debated by scientists. What is certain is that the current composition of the Earth's atmosphere is the result of a long evolution, which began at the time of the creation of planet Earth: volcanic activity, photosynthesis, the action of solar radiation, oxidative processes and microbial activity have modified its composition over time until the current equilibrium was reached.

The first atmosphere that developed around planet Earth during its creation was probably made up of the gases present in the nebula that gave rise to the solar system, attracted by the force of gravity of the newborn planet. This atmosphere is thought to have consisted mainly of hydrogen (H2), together with other gases such as water vapour (H2O), methane (CH4) and ammonia (NH3). From the moment the solar wind swept away what was left of the solar nebula, however, this primary atmosphere was probably also swept away.

According to the most widely accepted hypotheses, the water vapour, nitrogen (N2) and carbon dioxide (CO2) currently present in the atmosphere can be attributed to volcanic activity and chemical reactions that took place around 3.8 billion years ago, when the Earth already had a surface crust and its temperature was low enough to prevent gases from the interior of the planet from escaping into space. Alternative models, based on the study of gases released by meteorite impacts on the developing Earth, lead to the description of a primordial atmosphere composed of methane, hydrogen, water vapour, nitrogen and ammonia.

Until 2.45 billion years ago, there was no oxygen (O2) in the Earth's atmosphere. Oxygen is thought to have formed later, either by decomposition of water vapour under the action of electrical discharges and solar radiation in the upper atmosphere, or as a product of photosynthesis, which became active after the first autotrophic organisms appeared on Earth 2.45 billion years ago.

Reasons why the atmosphere is useful

The atmosphere protects Earth from harmful solar radiations and regulates heating provided by the Sun. The first function is made possible by ozone existing in the stratosphere, the second function is achieved by a mix of gases existing in the whole atmosphere called “greenhouse gases”. Ozone accumulating in the stratosphere (called “stratospheric ozone”) is crucial for the survival of life on Earth as it constitutes a sort of natural screen for a part of solar radiations that are invisible to humans and are located in the ultraviolet region (frequency from 100 to 400 nm). If these radiations reached the soil they would cause genetic mutations, skin tumours and many other damages to flora and fauna. Moreover, stratospheric ozone plays a fundamental role for the formation of clouds and rain as it heats up and blocks water vapour in the lower layers of the atmosphere. Greenhouse gases, instead, are responsible for the heating of the lower atmosphere and Earth’s surface. The characteristic of these gases, infact, is being transparent to light radiations (short-wave) coming from the Sun and absorbing thermal radiations (long-wave)

emitted and diffused on Earth’s surface. As panes in a greenhouse, they allow the entrance of solar light radiations but intercept thermal radiations coming back from Earth’s surface, thus keeping high the temperature in the lower atmosphere.
The most important greenhouse gas is water vapour which, alone, manages to make the atmospheric temperature rise by about 30°C. In order of importance follow carbon dioxide (CO_2), methane (CH_4), nitrogen oxides (NOx) and ozone (O_3).

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