Oxygen – more than just hot air

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Oxygen is ubiquitous – in air and bound in water and in many other substances around us in our daily life. The colourless gas is full of surprises as the following article shows.

Oxygen (O) occurs in air as a diatomic gaseous O_2 molecule and in combination with other chemical elements it is, until deep into the earth crust, the most frequent element on our planet.

Oxygen compounds

Compounds of oxygen with other elements are called oxides. While water as a liquid oxide of hydrogen presumably is the most frequent ingredient in cosmetics, the solid oxides comprise many pigments as for instance iron oxides (red, brown, black) and titanium dioxide (white). Silicon dioxide (quartz), aluminium oxide (clay) and iron oxides are the main ingredients of healing earths used in masks or in physiotherapeutic applications.
Besides the inorganic compounds there is a multitude of organic oxygen compounds. Among them are alcohols such as ethanol (solvent) or glycerine (a component of the NMF), many odorous substances based on aldehydes and ketones, carboxylic acids (example: saturated and essential fatty acids) as well as their compounds among each other. The triglycerides of glycerine and carboxylic acids are main ingredients of herbal oils and animal fats.
Bound oxygen also occurs in amino acids, peptides and proteins, and in phosphoric compounds in living nature. Oxygen-free compounds such as the squalene of the human sebum rather are an exception in this context.

Controlled reactions

Oxygen reacts with combustible, or in other words, oxidisable substances while releasing energy that our body uses for the maintenance of the body temperature and for the provision of mechanical energy in our muscles. The human cells have specific organelles available for this purpose; they are called mitochondria. In the mitochondria, the oxidations including radical reactions take place in a biochemically controlled way. Enzymes catalyse the different reaction steps (oxidoreductases). End products are carbon dioxide which is exhaled, as well as water and oxidised organic compounds that are mainly excreted via faeces and urine.
Since from a physical point of view the oxidation process always is coupled with an electron transfer from the substance oxidised to the oxygen, we generally also speak of oxidation when, in one way or other, electrons are withdrawn from a substance. During the photosynthesis of plants generating oxygen from water, the oxidation of the water-bound oxygen (O^{2-}) into gaseous oxygen (O_2) occurs with releasing electrons.

Harmful substances forming with oxidation

Outside of the mitochondria the uncontrolled radical oxidations can be harmful. That is why the cells of organisms are protected by antioxidants such as vitamin C (ascorbic acid) and vitamin E (tocopherol). In the skin barrier the amino acids of the Natural Moisturizing Factor (NMF) and certain peptide structures are particularly effective against oxidising atmospheric radicals such as nitrogen oxides.
Outside of the organisms the photochemical oxidation of organic compounds generates many harmful substances such as peroxyacetyl nitrate (PAN) contained in atmospheric smog or allergenic peroxides from essential oils. Rancid smelling cleavage products result from the peroxidation of unsaturated carboxylic acid. Sometimes also ozone (O_3) which consists of 3 oxygen atoms can participate in the oxidations.

Aggressive radicals

Particularly aggressive radicals besides ozone (O_3) and the energy-rich singlet oxygen ($^1O_2$) are peroxide anion (O_2^{2-}), hydroxyl radical (HO•) and the hyperoxide anion alias superoxide anion (O_2^-). They belong to the group of ROS (Reactive Oxygen Species). Also the organic hydroperoxides (R-OOH), peroxy radicals (R-OO•) and alkoxy radicals (R-O•) that result from the uncontrolled reaction with organic compounds are particularly reactive and harmful. In order to avoid such formation and to protect against them, food, cosmetic products and many other items of the daily life are supplemented with antioxidants. Their principle is to react with the ROS before the reaction with the compounds to be protected can occur. The antioxidants are used up during this process, though. In sun protection products, the cosmetic industry chooses another principle. By means of UV filters the radiation is already transferred into heat before the radicals can form.

Reactions in and under the skin

The damages of the skin lipids („lipid peroxidation“) or the skin proteins („protein oxidation“) can trigger inflammation- and aging processes, DNA damages, as well as skin alterations up to carcinomas. Visually recognizable are the age spots consisting of oxidised protein-lipid-complexes (lipofuscin) or sugar-protein-agglomerates (Advanced Glycation Endproducts [AGE]). During normal physiological metabolic activity and in the case of immune responses the body itself uses the aggressive ROS molecules. An example here is hydrogen peroxide (H_2O_2), which the body needs for specific enzyme-controlled biochemical reactions. Surplus hydrogen peroxide is degraded into water and oxygen by the enzyme catalase (CAT) and to water by means of the selenium-containing glutathione peroxidase (GPX). In this way it cannot lead to damages in the organism unless there is an enzyme deficiency. Vitiligo (skin depigmentation) can be mentioned as a visible consequence of an enzyme deficiency. In this case not degraded hydrogen peroxide affects the melanin and the melanin formation process. The consequence is that unpigmented areas on the skin appear. A similar effect can be observed during the bleaching process of skin and hairs by means of hydrogen peroxide.
Also the skin flora has specific enzymes that can oxidise and degrade the lipids. In this process, among other substances, short-chained carboxylic acids develop which form the protective acid mantle of the skin by reducing the pH level.

Aseptic effects

Reactive oxygen compounds have aseptic effects in the case of infections and mycoses of the skin surface. Examples are benzoyl peroxide to treat acne symptoms. Low-concentrated hydrogen peroxide solutions are used to disinfect larger areas of objects. In this process highly reactive, nascent (monoatomic) oxygen is released. Frequently used oxygen-releasing compounds are potassium permanganate which is a very effective remedy in the case of fungus- and other skin infections, as well as alkaline hypochlorite solutions (oxidative cleaners).
Cosmetic high frequency instruments produce low amounts of ozone and nitrogen oxides that have disinfecting effects during the cleansing of acne comedones or during the treatment of inflamed skin areas. Cosmetic vaporizers (Vapozon) produce ozone by means of a UV light emitting quartz lamp.

Dr Hans Lautenschläger