

FREE RADICALS IN BIOLOGY AND ENVIRONMENT

[Professor Alexander Tkac](#)

Institute of Physical Chemistry
Slovak Technical University
Slovak Republic

Free radicals, as particles with unpaired electrons and a broad scale of reactivity, have played a dominant role from the beginning of the evolution of the universe through the gradual enrichment of our planet with biradical molecular oxygen, resulting from the photodecomposition - photolysis - of H₂O, and up to energy gain in biology through respiration, which maintains the flow of life in its narrow physical and chemical limits. While in the environment the level of free radicals is conditioned by the intensity and the abundance of photons of the interacting radiation, in biological systems the reactivity of radicals is bonded to the catalytic action of transition metals. The combined effect - initiation of reactive radicals by photon absorption or by catalytic electron transfer from transition metals - proceeds in the interface layer between a biosystem - skin, green plants - and its environment. Radiation effects inside a living system - lungs, bones - can also be induced by contamination with radioactive elements, i.e. Sr90 or radon.

With the introduction of an EPR flow-technique, the presence of H⁺, D⁺, O₂⁻, N₃⁻, OH⁻ and OOH⁻ radicals, generated by the atomisation of H₂, O₂ and N₂ gases and H₂O, D₂O, H₂O₂, NH₃ vapours in cold microwave plasma at 2450 MHz and 5-100 W, was confirmed. The reactivity of these radicals with diamagnetic gases and vapours during collisions in a cross-flow experiment in the resonance cavity of the EPR spectrometer simulates reactions in the atmosphere as well as in interstellar space. Under the influence of intense electromagnetic fields and electrical discharges the hydroxyl OH⁻ and hydroperoxy OOH⁻ radicals catalyse the oxidation of NO and SO in humid conditions to H₂SO₄ and NHO₃ acids and they are, hence, the source of acid rain.

The atmosphere of the planet is also contaminated with combustion products such as polyaromatic carcinogens. The radical chemistry of combustion was studied on a model of diffuse, oscillating and premixed H₂/O₂ flame, in the resonance cavity of the EPR spectrometer. The transfer of one electron to O₂ or to peroxides, under physiological conditions, leads to the generation of radicals with different reactivity.. Such a redox step in living organisms proceeds, either under enzymatic control in separated compartments without disturbances to the reductive bio-environment, or the radicals are generated randomly in the presence of potential electron-donors. The stepwise elimination of free radical trappers during thermal or oxygen stress leads to uncontrolled radical reactions that take part in different pathogenic processes, such as the peroxidation of lipids and membrane depreciation, inflammatory and autoimmune processes, injuring of mitochondria and of ischemic cells during reperfusion, and inclusive activation of oncogens or deactivation of antioncogens by chemical carcinogens.

The accumulation of peroxides leads to the formation of co-ordinated peroxy radicals stabilised on hemoproteins (catalase, HR-peroxides, cytochrome-oxidase, haemoglobin) in non-polar solvents, when other co-ordination agents are absent. The simultaneous application of the EPR and Clark membrane electrode techniques, in combination with spin-trappers DMPO, has shown the principal differences in the radical chemistry of healthy and tumorous mitochondria, isolated from liver cells.

Controlled radical reactions also play a dominant role in the protection of cell identity in the course of an immunological attack, involving the transformation of thermodynamic disequilibrium - characteristic of vital differentiated biosystems, i.e. heart rhythm and breathing - into thermodynamic equilibrium, a state connected with the stepwise slowing down of the life supporting bioprocesses, i.e. ageing and degenerative diseases.

An important positive role must also be ascribed to the synergistic antioxidant system of vitamins C and E, and NADPH. This system, in physiological conditions, eliminates the primary reactive radicals producing secondary radicals, with stepwise increased stability and, in this way, a hydrogen atom transfer cascade is finally closed with the regeneration of vitamin E. A similar role is played by the radical injury of antioncogens coding for metalloproteins (superoxodismutase, catalase, glutathione-reductase, cytochrome-oxidase) that control the level of superoxides and peroxides at the cell level. This is also true for the irreversible oxidation of biostructures, followed by their decompartmentalisation, DNK injury and production of insoluble sediments, as is the case in the brain, preceding the loss of memory in Alzheimer's disease or of mobility in Parkinson's disease.

Professor **Alexander Tkac** holds a Ph.D. in physical chemistry from Comenius University, Bratislava, and a Doctor of Sciences degree from Charles University, Prague. In 1965 he was nominated for the Czechoslovak State Prize for Sciences. In 1989 he became Vice-Rector for

Sciences and Foreign Affairs at the Slovak Technical University, and, in 1992, he received the "Gold Medal of Jaroslav Heyrovsky" from the Slovak Academy of Sciences and the "Medal of Emil Votocek for Merit in Science and Technology" from the University of Chemical Technology in Prague. Professor Tkac was also elected President of the Slovak Group of the Society of Arts and Sciences at the International Centre in Washington, USA.