On the mechanism of action of fullerene derivatives for superoxide dismutation

Sílvia Osuna, Marcel Swart and Miquel Solà

We have studied the mechanism of action for the antioxidant activity of C_{60} derivatives at the BP86/TZP level including solvent effects (DMSO) using the COSMO approach. The reaction studied here concerns the degradation of the biologically important superoxide radical ($O_2^{\cdot -}$) that is linked to tissue damage in several human disorders. Several fullerene derivatives had experimentally been shown to be protective in cell culture and animal models of injury, but precisely how these compounds protect the biological systems is still unknown. We have investigated the activity of tris-malonyl C_{60} (also called C_3) that efficiently removes the superoxide anion with an activity within the range of several biologically effective, metal-containing SOD mimetics. The antioxidant properties of the C_3 compound are attributed to the high affinity of C_{60} to accept electrons. Our results show that once the superoxide radical ($O_2^{\cdot -}$) is in contact with the surface of the C_3 compound, the unpaired electron of the superoxide radical is transferred to the fullerene. This process, which converts the damaging superoxide $O_2^{\cdot -}$ to neutral oxygen O_2, is actually the rate-determining step of the reaction. Afterwards, another superoxide radical reacts with the $C_3^{\cdot -}$ radical to form hydrogen peroxide H_2O_2 and in the process takes up the additional electron that was transferred in the first step. The overall process is clearly exothermic and, in general, involves reaction steps with relatively low activation barriers. The capability of the C_3 compound of degradation of the highly reactive oxygen species that is linked to several human diseases is of immediate interest for future applications in the field of biology and medicine.