Quests at the edge of bionanoscience and quantum biophysics: Impact of the interaction of globular proteins with a variety of external effectors on their stability and function

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The main goal of our research is a comprehension of fundamental physical principles that determine intrinsic links between the stability, flexibility and function of globular proteins. Our approach implies the complex application of diverse, preparative, kinetic and thermodynamic experimental methods at the edge of bionanoscience and quantum biophysics, and the subsequent synergic analysis of obtained results on the basis of state-of-the-art theoretical notions.

We studied an impact of the organic substance being of a biomedical importance, dimethyl sulfoxide (DMSO), on the characteristics of functional activity and thermal stability for the protein that is well-known for its quantum catalytic mechanism, α-chymotrypsin (α-CT), under the broadly variable concentration conditions for the DMSO additive. It has been established that, thanks to the peculiar structural constitution of this protein, at moderate additive concentrations, around the pH values of 8.1–8.4, the mechanism of the DMSO-protein interaction for the relatively rigid (carrying platform) and much more flexible (active cite) parts of α-CT is essentially different, displaying stabilizing and destabilizing patterns, respectively. The physical nature for this difference has been thoroughly analyzed.

Furthermore, in cooperation with the Universities of Pittsburgh and Erlangen, we have studied the charge transfer (electron tunneling) mechanisms for a redox-active blue copper protein, Azurin (Az), under the condition of its immobilization within the multilayer bionanodevices. Az thin films, thanks to the intermediary role of self-assembled alkanethiol monolayers (SAMs), form sanswich-like structures on gold platforms, Au/SAM(n)/Az (where "n" is a number of carbon atoms within the alkanethiol chains; here n=4). Within these nanodevices, along with usual buffered liquids, as the external media, we have applied concentrated aqueous solutions of ultraviscous protic ionic melt, choline dihydrogenphosphate ([ch][dhp]). In addition, the temperature and pressure variations have been applied within the sufficiently broad ranges. We have disclosed that the additional confinement of a protein globule within the ultraviscous semi-rigid environment causes essential restriction of protein's intrinsic flexibility (conformational dynamics), especially under high pressure or/and low temperature settings. This, in turn, leads to the appearance of a couple of kinetic "anomalies" (deviations from the traditional shapes of kinetic relationships), caused by the intercept of a dynamically controlled (adiabatic) kinetic pattern (that is characteristic for this kind of systems), with the newly emerging nonergodic and nonlinear kinetic motifs.

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