Sol–Gel Materials as Efficient Enzyme Protectors: Preserving the Activity of Phosphatases under Extreme pH Conditions

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Abstract: By entrapment in (surfactant modified) silica sol–gel matrixes, alkaline phosphatase (AlP) — naturally with optimum activity at pH 9.5 — was kept functioning at extreme acidic environments as low as pH 0.9, and acid phosphatase (AcP) — naturally with optimum activity at pH 4.5 — was kept functioning at extreme alkaline environments, up to pH 13.0. Propositions are offered as to the origin of the ability of the matrixes to provide such highly efficient protection and as to the origin of the synergetic enhancing effect when both the silica and the surfactants are used as a combined entrapping environment. It was found that the protectability of the enzymes against harsh pH values is dependent on the nature of the surfactant.

Background

As the name of the enzyme alkaline phosphatase (AlP) implies, its catalytic activity (hydrolysis of phosphoesters to phosphate and to the corresponding alcohol or phenolate) is optimal at basic pH values (9–10). Here, we show that by utilizing the protective features of sol–gel materials, one can keep this alkaline enzyme active under extreme acidic conditions, going down the pH scale to as low as pH 0.9!, and that when, for comparison purposes, the acidic enzyme acid phosphatase (AcP, optimal performance at pH 4.5–6.0) is entrapped in these materials, it is kept active under extreme alkaline conditions, as high as pH 13. Silica-based sol–gel materials, with and without surfactant modification, were the key to these unusually large effects, which amount to practical alteration of the classical phosphatases’ properties.

We recall that sol–gel materials have proven in the last two decades to be versatile carriers of active dopants. Diverse reactive functionalities have been introduced into these materials by either direct physical doping or covalent attachment. Of the various families of functional sol–gel materials that have been developed, one, which has progressed particularly fast, has been the family of sol–gel materials with biochemical and biological activities. Enhanced stability of entrapped bio-


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