

POTENTIAL PROTOENZYMES: PREBIOTICALLY PLAUSIBLE HYPERBRANCHED POLYMERS.I. Mamajanov^{1a} and G. D. Cody^{1b}¹Geophysical Laboratory, Carnegie Institution for Science, 5251 Broad Branch Rd., Washington, DC 20015.^aimamajanov@carnegiescience.edu^bgcody@carnegiescience.edu

Introduction: Enzymes are highly selective macromolecular catalysts that govern biochemical reaction networks. Enzymes consist of organic or metallic cofactors scaffolded by intricate three-dimensional protein or RNA structures that bind, encapsulate and favorably orientate substrates that are about to undergo a biotransformation. Extended protein and/or RNA biomacromolecules employed by contemporary enzymes are unlikely to have been available at the early stages of chemical evolution. In view of this we explore alternative prebiotically plausible catalyst scaffolds.

In the synthetic polymer community one of the well-known structures used for enzyme mimics are dendrimers, regular tree-like, or hyperbranched, polymers. The topology of a dendrimer enforces globular structure and allows for controlled microenvironment surrounding its core and for artificial enzyme design. This concept pioneered by Breslow and coworkers has been successfully implemented for multiple biomimetic processes.¹ From the prebiotic chemistry perspective, regular dendrimers are unlikely protoenzyme candidates since they are difficult to synthesize. Irregular dendrimers, or hyperbranched polymers (HBPs), on the other hand, are often straightforwardly synthesized in one-pot process.² Similar to dendrimers, the highly branched structure of HBPs results in a multitude of end groups that can bind catalysts and substrates, as well as controlling the polarity of the intramolecular microenvironment, albeit in less controlled fashion.² Prebiotic synthesis and function of HBPs are the subject of this study.

Hyperbranched Polyesters: In a previous study we have demonstrated a facile polyesterification of L-malic acid under prebiotically plausible conditions involving mild heat and dehydration.³ Employing similar conditions, we have successfully polymerized multifunctional monomers, including aldonic acids, mixtures of various di-carboxylic acids and hydroxy acids with tri-functional alcohols, glycerol and 1,1,1-tris(hydroxymethyl)propane. In the case of citric acid and glycerol polyesterification, the polymerization products consisted of a mixture of isomeric structures of varying molar mass (up to dodecamers) as evidenced by NMR, mass spectrometry and size-exclusion chromatography. Addition of divalent cations during polymerization resulted in increased incorporation of citric acid into the polymers and the

evident formation of cation-HBP complexes. The chelating properties of citric acid direct the composition of the resulting HBP, turning the polymerization system into a primitive smart material.⁴

Catalytic Properties: In the context of exploring the catalytic properties of HBPs we have studied the effects of these macromolecules on Kemp elimination reaction⁵ and Knoevenagel condensation test reaction.⁶

Kemp elimination is a base-catalyzed ring opening of benzoxazole by cleaving an NO bond along with deprotonation of carbon to result in *o*-cyano phenol derivative. The rate of the reaction is highly sensitive to solvent polarity, and therefore is a good monitor for the polarity of a range of HBP microenvironments.

Knoevenagel condensation is an example of a reaction forming a C-C bond in water solution, a nucleophilic addition of an active hydrogen compound to a carbonyl compound followed by dehydration. We have established that hyperbranched polyimines and polyester complexes efficiently catalyze Knoevenagel reaction.

Summary: A number of HBPs can be synthesized via facile routes, some of which can be translated into prebiotic scenarios. Structural and catalytic properties of HBPs formulate new attractive avenues for prebiotic chemistry research. Herein we report the synthesis of HBPs under mild conditions, metal binding and smart material behavior of citric acid/glycerol polyester, as well as catalytic properties of hyperbranched polyesters and polyimines.

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