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PREBIOTIC CHEMISTRY

Catalysis of Glyceraldehyde Synthesis by Primary or Secondary Amino Acids Under Prebiotic Conditions as a Function of pH

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Abstract The synthesis of an excess of D-glyceraldehyde by coupling glycolaldehyde with formaldehyde under prebiotic conditions is catalyzed by L amino acids having primary amino groups at acidic pH's, but at neutral or higher pH's they preferentially form L-glyceraldehyde. L Amino acids having secondary amino groups, such as proline, have the reverse preferences, affording excess L-glyceraldehyde at low pH but excess D-glyceraldehyde at higher pHs. Detailed mechanistic proposals make these preferences understandable. The relevance of these findings to the origin of D sugars on prebiotic Earth is described.

Keywords Amino acids · Sugars · Amplification · Chirality · Aldol · Earth

Introduction

One of the most interesting questions about the prebiotic world has to do with homochirality—how did the L amino acids and D sugars form on Earth so polypeptides and nucleic acids could have well-defined structures, not as racemic or diastereomeric mixtures? We have described how meteoritic α-methyl amino acids, arriving on Earth with modest enantioexcesses of the S configuration, can generate normal L amino acids by a decarboxylative transamination under prebiotic conditions (Breslow and Levine 2006; Levine et al. 2008; Breslow et al. 2010; Breslow 2011). We and others have shown how the resulting small excesses can be amplified under either equilibrium (Morowitz 1969; Breslow and Levine 2006; Klussman et al. 2006, 2007; Hein and Blackmond 2012) or kinetic (Breslow et al. 2010; Breslow 2011) conditions to high enantioexcesses of the L configuration in water solution. We assume that the prebiotic processes occurred in water solution at moderate temperatures on the surface of the Earth where meteorites had landed.

In a preliminary publication we also described the formation of D-glyceraldehyde by aldol addition of formaldehyde to glycolaldehyde catalyzed by amino acids (Breslow and Cheng 2010). We found that all the L amino acids we examined preferentially formed an excess of D-glyceraldehyde with one exception; L-proline catalyzed the preferential formation of an excess

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