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Survivability of amino acids in oceanic hydrothermal systems

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Amino acids are building blocks for life. The relative abundance and survivability of amino acids in natural hydrothermal systems play a critical role in the synthesis of biomolecules, and possibly, for the origin of life in early Earth or extraterrestrial oceans. Identifying the reactivity, pathways, and reaction mechanisms of amino acids under hydrothermal conditions will help to understand how they can survive and transform in relatively extreme environments. The stability and fate of amino acids in oceanic hydrothermal systems can be affected by fluid chemistry and composition including the presence of inorganic materials. However, their specific effects and underlying mechanisms remain largely unexplored. In this study, we examine the survivability and pathways of amino acids in hydrothermal fluids with a wide range of pH and a variety of metal salt compositions. Using phenylalanine as a model compound, we find that decarboxylation is the primary degradation pathway for amino acids followed by deamination, via either substitution or elimination. Amino acid reactivity is influenced by solution pH, with degradation being strongly inhibited under highly acidic or alkaline conditions. The presence of dissolved metal salts not only changes the distribution of decarboxylation and deamination products but also plays a protective role, inhibiting the decomposition of amino acids. Overall, this study suggests that both relatively extreme pH and surrounding metal salts could enhance the survivability of amino acids, which may provide new insights into understanding the preservation and distribution of amino acids in oceanic hydrothermal systems on and beyond Earth.