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Amino acid synthesis driven by ferroan brucite-mediated chemistry

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All known life uses amino acids, so investigating plausible abiotic synthetic pathways that could form such compounds on early Earth and other bodies will constrain where and how life originated. One such pathway, reductive amination, is the reaction between an amine, carbonyl, and reducing agent. When ammonia and a keto acid react via this pathway, the product of this reaction is an amino acid. Minerals such as green rust and iron sulfides have been demonstrated as prebiotically plausible reducing agents that can catalyze reductive amination reactions.[1,2]

However, known reductive amination pathways require ammonia, whose concentrations both could vary across environments and are poorly constrained on early Earth. Nitrate provides an alternate nitrogen source that could be present at millimolar levels in the Archean oceans.[3] Ferroan brucite, $Fe_{0.33},Mg_{0.66}(OH)_2$, which is present in terrestrial and submarine ultramafic rock-hosted systems undergoing olivine hydration, can reduce nitrate into ammonia. Here, we explore whether ferroan brucite can catalyze the formation of amino acids. Specifically, we test whether ferroan brucite mediates the reduction of nitrate and subsequent reaction with pyruvate required to form alanine. Pyruvate and nitrate are covaried in equal quantities from 1 mM to 250 mM and tested over timescales of 2 days to 14 months. The reaction forms trace amounts of alanine and glutamate and up to 1% yield of its main amino acid product, glutamine. To form glutamine, we propose that pyruvate first polymerizes on the brucite surface then must lose a carbon and have one carboxyl group convert to an amide, which we are testing using labelled carbon substrates coupled with NMR and GC-MS analysis. In addition to providing a novel route to synthesize glutamine, this synthetic pathway demonstrates a novel method of C-C bond cleavage on a common serpentinization product.

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