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Chemical Kinetics as a Window into Prebiotic Plausibility

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Origin of Life research has gained significant momentum in recent years as an endeavour requiring interdisciplinary collaboration [1]. Despite this, many groups work in isolation, leading to an ongoing disconnect between the geochemistry and prebiotic chemistry communities. This lack of cohesion stems from the absence of effective tools to assess the likelihood of specific synthetic pathways occurring within proposed geochemical environments.

How can we bridge the gap between laboratory experiments and geochemical environments? We believe that chemical kinetics is key to answering this question [2], making the measurement of rate constants for prebiotic reactions a priority [3]. Life exists in disequilibrium with its environment, harnessing this imbalance to drive essential processes [4]. Therefore, it is crucial not only to consider which reactions are thermodynamically feasible but also those which are kinetically favourable under specific conditions, such as pH, UV irradiation, and the presence of catalysts. Thus, an aqueous chemical kinetics model, informed by experimental data, could serve as a foundation for linking laboratory chemistry to realistic geochemical settings. Such a model would enhance our understanding of the requisite conditions for prebiotic syntheses and reveal how evolving aqueous environments influence the progression of a reaction network. Moreover, this model could elucidate how different proposed prebiotic pathways might interact, providing insights into their potential synergy or competition.

Here we present a preliminary aqueous chemical kinetics model alongside a nascent database for prebiotic chemical reaction networks. Development and implementation of this tool will require overcoming major gaps in experimental data, as well as the obstacles inherent in interdisciplinary collaboration. Despite these challenges, we believe that the development of a predictive prebiotic kinetics model could spark a paradigm shift in how we study life's emergence.

[1] Powner & Sutherland (2011), *Philosophical Transactions of the Royal Society B* 366, 2870-2877.

[2] White & Rimmer (2025), *Accounts of Chemical Research* 58, 1-10.

[3] White et al. (2024), *ACS Earth and Space Chemistry* 8, 2110-2345.

[4] Smith et al. (2021), *Life* 11, 498.