New Estimates of Nitrogen Fixation on Early Earth

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For millennia, humanity has wondered if there might be other life present in the universe. Today, we have the technological capabilities to begin to understand what conditions allow for life to exist. Fixed nitrogen species generated by the early Earth's atmosphere are critical for the emergence of life. We present an updated estimate of nitrogen fixation on the Hadean Earth that replaces outdated information and includes new, crucial components. We use CEA (Chemical Equilibrium with Applications) to estimate lightning-induced NO and HCN formation in an N2/CO2-dominated atmosphere and consider nitrogen fixation stimulated by solar energetic particle deposition throughout the atmosphere, and KINETICS (the 1-D Caltech/JPL photochemical model) to assess the production of fixed nitrogen species that rain out into the Earth's early ocean. We study the impact of a novel reaction pathway for generating HCN via HCN2, inspired by recent experimental results. Additionally, we estimate the steady-state concentration of fixed nitrogen species in the Hadean ocean, considering loss by photoreduction of NOx and hydrolysis of HCN. Our three major results are: 1) new estimates of fixed nitrogen that would be accessible to early life (summed, 4.1x10-4–1.0x10-5M); 2) HCN2 reactions increase the amount of HCN created five-fold; 3) the common result of CO runaway may be physical in CO2-rich atmospheres rather than a numerical issue. These results provide a clearer planetary context for future studies regarding the emergence of life. This steps us closer to answering the age-old question: are we alone in the universe?

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