

Experimental study on photochemical synthesis of building blocks from the CO/N₂O route on terrestrial planets

XIAOFENG ZANG¹, KOTA MOORI¹, ANDY FONG²,
YUTA ASAKURA¹, TAKUMI UDO³, YOKO KEBUKAWA¹,
KENSEI KOBAYASHI^{1,3} AND YUICHIRO UENO^{1,4,5}

¹Institute of Science Tokyo

²Massachusetts Institute of Technology

³Yokohama National University

⁴Earth-Life Science Institute

⁵JAMSTEC

Synthesis of building block molecules is crucial to understand the origins of life. Atmospheric UV photochemistry from CO₂ and CO is a plausible mechanism to generate organic compounds on terrestrial planets such as Earth and Mars [1]. In our previous study, it was demonstrated that solar UV irradiation to atmospheric N₂O under the presence of CO or H₂ with liquid water produce NH₃ as well as several simple amino acids [2]. Therefore, UV chemistry from CO/HCHO and N₂O/NH₃ is an alternative pathway to form amino acids or other building blocks without HCN. Here, we report further analysis of the experimental products systematically. After UV irradiation to CO, N₂O and H₂O, the samples were measured using HPLC-Orbitrap MS. The experiments yielded a variety of amino acids, imidazole, HMT and its derivatives, as well as some isomers of nucleobases. Among these products, HMT is the most abundant and formed by the reaction between HCHO and NH₃, which are produced from CO and N₂O, respectively. Furthermore, glycolaldehyde and glyoxal were determined and could initiate synthesis of further organic acids, sugars, and sugar acids. The amount of amino acids and glycolate increased largely when the products were hydrolyzed with 6M HCl at 110°C for 24 hours. Combining these results, amino acids as well as other building blocks were synthesized from HCHO and NH₃ through formose-type reaction, not via hydrogen cyanide (HCN) as an intermediate. Further amino acid analysis and mechanisms will be discussed elsewhere in the conference (Asakura et al., in this volume). Based on the experimental results, the actual production rate of free glycine was estimated to be $1.2 \times 10^6 \sim 6.0 \times 10^7$ kg/yr when an atmosphere containing 1% of CO and 3000 ppbv N₂O. Our study demonstrated that the CO/N₂O route could be a plausible mechanism to provide significant amounts of building block molecules on early Earth or Mars.

[1] Ueno, Y., Schmidt, J.A., Johnson, M.S. et al. (2024) *Nat. Geosci.* 17, 503–507.

[2] Zang X., Ueno Y., and Kitadai N. (2022) *Astrobiology*, 22: 387-398.