Abiotic Nitrogen Fixation and Organic Synthesis by Photochemistry on Early Mars

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Detailed studies of Mars in recent years have provided many progress on understanding the possible view of environment on early Mars. With the fact that liquid water was present on early Mars, and the discovery of organic molecules as well as nitrogen-bearing compounds on Mars, there is possibility that life could have emerged on early Mars. Thus, it is important to understand the abiotic organic synthesis and nitrogen fixation process to evaluate the possible origin of life on Mars or other terrestrial planet. Previous studies suggested that organic matters can be produced by photochemistry. Total pressure of Martian atmosphere is lower than Earth. Thus, UV may penetrated down to the surface and can directly photolyze liquid water. This suggests that UV-induced photochemistry may have been more important. However, little is known about abiotic nitrogen fixation by UV light. This experimental study examines the nitrogen photochemistry at the surface of water. In the experiment, initial gas contains N₂O or N₂ with or without CO under the presence of liquid water. The starting condition may have existed on early Mars. The results showed that NH₃, methylamine, glycine and other amino acids was produced from N₂O + CO + H₂O, whereas only trace amount of NH₃ was formed from N₂ + CO + H₂O. When gas phase do not contain CO, nitrate and nitrite were produced instead of NH₃. A numerical model including 296 photochemical reactions was constructed, and can qualitatively explain the formation of NH₃ from N₂O. However, the concentration of NH₃ in the model is order of magnitude lower than the observed amount in the experiment, suggesting that current photochemical model still lack some possible reactions to generate NH₃. The results provide important insights on chemical evolution theory that lead to the origin of life and the atmospheric evolution on Mars when the reaction pathway of NH₃ starting from N₂O and N₂ by UV light is confirmed.

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