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Method Development of Uracil Kinetic Degradation to Measure Position-Specific Stable Carbon Isotope Values

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The NASA Astrobiology Strategy has inspired research to characterize the “biosignature threshold” of a compound being synthesized by either an abiotic or biotic mechanism. The difficulty in determining a biotic and abiotic chemical signature is based on the variance of source pools and synthesis pathways. Investigating these details can help us clarify what to expect when faced with a sample from early Earth or extraterrestrial material. Hence, studying molecules that are ubiquitous to life, and have been found in meteorites, are crucial to studying origins of life questions.

The pyrimidine, uracil, which is a ribonucleic acid (RNA) nucleobase, has been found on carbonaceous chondrites such as the Murchison meteorite. Uracil’s importance comes from the RNA world hypothesis that suggests that RNA evolved before deoxyribonucleic acid (DNA). RNA is the single-stranded version of DNA with a different nucleobase: uracil. While uracil is found in RNA, thymine, a methylated version of uracil is found in DNA. The importance of RNA in the RNA world hypothesis comes from the idea that something as complex as RNA must have originated from simple molecules that evolved an ability to self-replicate.

Here we present a method that can successfully degrade uracil to measure a specific carbon (C-2), in the pyrimidine ring. The isolation of one of the carbons in uracil as CO_2 will help us understand the carbon fractionation and intramolecular variations associated with biological and abiological synthesis. The uracil was degraded using a catalyst and high temperature to break the ring into CO_2 and b-alanine products. Degradation was verified by using nuclear magnetic resonance (NMR), and the C-2 product was measured by isotope ratio mass spectrometry (IRMS) to evaluate the intramolecular stable carbon isotope value of the uracil standard.

Since uracil has biotic and abiotic synthesis pathways, it is important to have the ability to distinguish between them when uracil from an extraterrestrial source is measured. One way to differentiate between formation pathways is to use isotope analysis, specifically position specific isotope analysis (PSIA), to distinguish between the two processes. This work will help establish a baseline for intramolecular variation of abiotic uracil.