Sugar Derivatives in Residues Produced from the UV Irradiation of Astrophysical Ice Analogs

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A large variety of organic compounds of astrobiological and prebiotic interest have been detected in carbonaceous meteorites. These include amino acids, carboxylic acids, amphiphiles, functionalized nitrogen heterocycles such as nucleobases, functionalized polycyclic aromatic hydrocarbons such as quinones, and sugar derivatives. The sugar derivatives identified in the Murchison and Murray meteorites are mainly sugar alcohols and sugar acids, and only the smallest sugar (dihydroxyacetone) has been detected. The presence of such a variety of organics in meteorites strongly suggests that molecules essential to life can form abiotically under astrophysical conditions. This hypothesis is further supported by laboratory studies in which astrophysical ice analogs (mixtures of H_2O, CO, CO_2, CH_3OH, CH_4, NH_3, etc.) are subjected to ultraviolet (UV) irradiation at low temperature (<15 K) to simulate cold interstellar environments. These studies show that the organic residues recovered at room temperature after irradiation contain amino acids, amphiphiles, nucleobases, sugar derivatives, as well as other complex organic compounds. The finding of such compounds under plausible interstellar conditions is consistent with the presence of organic compounds in meteorites.

Until very recently, no systematic search for the presence of sugar derivatives in laboratory residues had been carried out. The detection of ribose, the sugar constituent of RNA in all living systems, as well as other sugars, sugar alcohols, and sugar acids have been recently reported in one organic residue produced from the UV irradiation of an $H_2O:CH_3OH:NH_3$ (10:3.5:1) ice mixture at 80 K. In this work, we present a detailed study of organic residues produced from the UV irradiation ice mixtures of several starting compositions (containing H_2O, CH_3OH, CO, CO_2, and/or NH_3) at <15 K for their sugar derivative content. Our results confirm the presence of all 3C–5C sugar alcohols, several 3C–5C sugars, and all 3C–4C sugar acids (in decreasing order of abundances) in the residues. The higher abundances of sugar alcohols in these residues suggest a pathway in which sugar alcohols are formed first, while the formation of sugars and sugar acids require more steps. Finally, our results are compared with the detection of sugars derivatives in primitive meteorites.