The Formation of Organic Compounds of Astrobiological Interest by the Irradiation Processing of Astrophysical Ices

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Many environments in space contain very low temperature mixed molecular ices that are exposed to ionizing radiation in the form of cosmic rays and high-energy photons. While traditional chemistry would not be expected to occur at the temperatures typical of these ices ($T < 50$ K), ionizing radiation can break bonds in the original molecules in the ices to form highly reactive ions and radicals. These ions and radicals are subsequently free to react despite the low temperatures of the original ices. Laboratory experiments, many of them carried out at the Astrochemistry Laboratory at NASA-Ames, show that the irradiation of ices made of even simple molecules like H_2O, CO, CO_2, CH_4, NH_3, etc. can result in the robust formation of large numbers of far more complex organic compounds. Many of these new products are of direct interest to astrobiology. For example, the irradiation of mixed molecular ices has been shown to produce amino acids, amphiphiles, quinones, sugars, heterocyclic compounds, and nucleobases, all molecular building blocks used by terrestrial life. Insofar as the presence of these materials plays a role in the origin of life on planets, this has profound implications for the potential abundance of life in the universe since these experiments simulate universal conditions that are expected to be found wherever new stars and planets form.