UV irradiation of pyrimidine mixed in ices of astrophysical interest: Formation of nucleobases and other pyrimidine derivatives

Michel Nuevo[1]

[1] NASA Ames

Astrochemistry laboratory simulations have shown that complex organic molecules, among which compounds of astrobiological interest such as amino acids, can be formed under interstellar/circumstellar conditions from the vacuum UV irradiation of interstellar ice analogs containing H2O, CO, CO2, CH3OH, NH3, etc.[1-3] Although the presence of amino acids in the interstellar medium (ISM) has not been confirmed yet, they are present in meteorites,[4-6] indicating that biomolecules and/or their precursors can be formed under extraterrestrial conditions. Nucleobases, the building blocks of DNA and RNA, have also been detected in meteorites,[7,8] broadening the variety of complex organic molecules that can be formed in space environments, but like amino acids they have not been observed in the ISM.[9] In this work, we study of the formation of pyrimidine-based organic compounds from the UV irradiation of pyrimidine (C4H4N2) mixed in H2O-, NH3-, and/or CH3OH-rich ices at low temperature, in order to simulate icy mixtures relevant to the ISM. Pyrimidine is the carbonaceous backbone for 3 biological nucleobases (cytosine, thymine and uracil). The results show that pyrimidine mixed in ices and subjected to UV photons leads to the formation of hydroxy/keto- (-OH/=O), amino- (NH2), and methyl- (CH3) pyrimidine derivatives. These products include the nucleobase uracil,[10] and possibly others. Finally, the photo-stability of pyrimidine and its photo-products, from their production to their survival at room temperature under our experimental conditions, will also be discussed.

References:
1. M. P. Bernstein et al., Nature 416, 401 (2002).
2. G. M. Mu_oz Caro et al., Nature 416, 403 (2002).
3. Nuevo, M. et al., Orig. Life Evol. Biosph., 38, 37 (2008).
4. Engel, M. H. and Macko, S. A., Nature, 389, 265 (1997).
5. Cronin, J. R. and Pizzarello, S., Science, 275, 951 (1997).
6. Cronin, J. R. and Pizzarello, S., Adv. Space Res., 23, 293 (1999).
7. van der Velden, W. and Schwartz, A., Geochim. Cosmochim. Acta, 41, 961 (1977).
8. Stocks, P. and Schwartz, A., Nature, 282, 709 (1979).
9. Charnley, S. B. et al., Adv. Space Res., 36, 137 (2005).
10. Nuevo, M. et al., submitted to Astrobiology, Dec. 2008.

Author:
Michel Nuevo, NASA Ames
Stefanie N. Milam, NASA Ames
Scott A. Sandford, NASA Ames
Jamie E. Elsila, NASA Goddard
Jason P. Dworkin, NASA Goddard