Phosphorus in the Early Solar System

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Phosphorus is a biologically important element- it plays major roles in both reproduction and metabolism. It makes up the backbone of DNA, is part of the primary energy source for life as ATP, is an important part of many other biomolecules, and forms bones as the mineral apatite. On the cosmologic scale, phosphorus is a minor element, and due to its position on the periodic table, phosphorus can behaves both as a siderophile and a lithophile in meteoritic systems, in part due to the wide variation in oxygen fugacity in the solar nebula. Additionally, much of the phosphorus on the earth is sequestered in the earth's core or is in the generally insoluble mineral apatite. Meteorites may have provided an important source of phosphorus for early life. The questions our research seeks to answer are: 1) In what form was meteoritic phosphorus delivered to the earth? and 2) How did phosphorus react to form a biologically useful compounds? These objectives will be accomplished by a combination of experiments and characterization of primitive meteorites.

Experimental Studies: The experimental work involves laboratory simulation of the first instance in the history of the solar system when P came into contact with warm, organic-rich, liquid water, i.e. aqueous alteration of P-rich, Fe-Ni alloys and related minerals on carbonaceous chondrite parent asteroids. A likely mechanism for the formation of P-bearing organic molecules is Fe,Ni-catalyzed organic synthesis during mild aqueous alteration on a small asteroidal body. Our initial experiments use distilled water in contact with a sample of metal with solar abundances of the elements Fe, Ni, Cr, Co, and P. Early results using an electron microprobe suggest that regions of corrosion form with increased concentrations of Cr and P- these sites may be important in releasing P into aqueous solution.

Characterization: There has only been one study of organic P chemistry in CM chondrites (Cooper et al. 1992). In this study, samples of the Murchison meteorite were leached using distilled water. The resulting leachates were then characterized using gas chromatography-mass spectrometry and ion chromatography. The methyl, ethyl, propyl, and butyl phosphonic acids were observed. These results have never been independently verified.

We have performed a series of dissolution experiments, analogous to those used by Cooper et al. (1992), on a suite of CM chondrites. Instead of the chromatography techniques, we analyze the fluids for P speciation using NMR and total P and phosphonates using wet chemistry. The results so far suggest that NMR is a useful technique for understanding meteoritic P chemistry. We have obtained clear signals of orthophosphate and from ethanephosphonic acid in Murchison, the first confirmation of the work of Cooper et al. (1992).