Origin of $^{17,18}$O-rich materials from Acfer 094.

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The mass-independent fractionation of oxygen isotopes in our Solar System is generally considered to have resulted from mixing of two isotopically distinct nebular reservoirs – $^{16}$O-rich and $^{17,18}$O-rich [1]. Recently we reported a discovery of a unique Fe-O-S-bearing material, called new-PCP, which is extremely enriched in $^{17}$O and $^{18}$O ($\delta^{17}$O and $\delta^{18}$O up to +180‰ relative to the Earth’s ocean) and may represents remnants of the $^{17,18}$O-rich reservoir in the early Solar System [2]. Here we report additional oxygen isotopic studies and thermodynamic calculations to constrain the origin of new-PCP.

Based on the unique chemical composition of new-PCP, hundreds grains of new-PCP were identified in an Acfer 094 polished thin section using FE-SEM-EDS. Four of these grains were selected to determine oxygen isotopic compositions and a degree of oxygen isotopic heterogeneity within the grains using isotopography [3]. All new-PCP grains analyzed are highly enriched in $^{17}$O and $^{18}$O relative to SMOW (~180‰) similar to the previously measured grains [2].

Mineralogical observations indicate that new-PCP could have formed by sulfurization and oxidation of Fe-metal and troilite [2]. To estimate the conditions for the origin of new-PCP, we carried out thermodynamic calculations in Fe-O-S system. Our calculations show that oxidation of troilite or metal could occur below 360K independent on total pressure under a constant $P_{H_2}/P_{H_2O}$ ratio of ~5x10$^{-4}$, a characteristic value for a gas of solar composition [4]. If the $P_{H_2}/P_{H_2O}$ ratio increases, formation of new-PCP occurs at higher temperature. The coexistence of magnetite and FeS with water below 373K is supported by experimental studies of [5].

Because water vapor ($H_2O$) is the major oxidizing agent in the solar nebula, the oxygen isotopic composition of the new-PCP probably corresponds to that of the nebular water. Because the sublimation temperature of water ice is below 200K even in the several-fold $H_2O$-enriched nebula, we infer that the new-PCP could have formed in the inner solar nebula before oxygen isotopic equilibrium had been achieved. Alternatively, the new-PCP might have formed in the Acfer 094 parent body prior to oxygen isotopic exchange between minor amounts of water and matrix silicates. These forming conditions are consistent with the lack of mineralogical and petrographical evidence of aqueous alteration of Acfer 094 [6].