Sulfur-bearing species in molecular clouds and PPDs as possible precursors for hydrated and dehydrated minerals in meteorites

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Chondritic meteorites are presumed to be fragments of planetesimals that formed in the solar protoplanetary disk (PPD). They nearly invariably contain hydrated and/or dehydrated minerals. The presence of those minerals is interpreted as evidence of aqueous or hydrothermal reactions between minerals and melted ice of interstellar origin during their evolution inside planetesimals [1, 2].

Conventionally, (pure) water ice is considered to be a sole source of aqueous fluid for the alteration reactions of minerals, owing to its high abundance in interstellar space [3, 4]. Thus, external heat sources that bring temperatures above zero Celsius are one of the necessary conditions for water-driven reactions to proceed. Recently a sulfuric acid (H_2SO_4-H_2O) that evolved from interstellar SO and SO_2 molecules through the PPD and planetesimal stages is proposed as a potential acidic alteration fluid at temperatures as low as -60°C, particularly for the planetesimal associated with Acfer094 chondrite [5].

Aqueous solutions of various electrolytes can simultaneously provide conditions of low temperature and a variable range in pH, thereby acting as different types of corrosive cryo-alteration agents within planetesimals. Here we report a possible cryo-alteration process that should work at high pH and is responsible for having formed tochilinite–cronstedtite mineral intergrowth commonly observed in CM chondrites.

We suspect two kinds of sulfur-bearing electrolytes as a potential cryo-alteration agent that should have given rise to the high pH in planetesimals. Ammonium hydrosulfide (NH_4SH) has been proposed to form at temperatures as low as 10K, from an ice mixture of ammonia (NH_3) and hydrogen sulfide (H_2S) [6]. Here we propose ammonium sulfide, $(NH_4)_2S$, as an alternative and more effective electrolyte to function as an alteration fluid in the CM parent asteroids. We carried out preliminary alteration experiments with mixed initial minerals of olivine + Fe-metal particles and ammonium sulfide solution as the alteration medium. The initial particles were immersed in the solution inside a microtube at room temperature for 1 to 4 weeks. After prescribed immersion period, a fraction of the solution was collected and dried on a Pt-grid. The residual minerals on the Pt-grid were observed with a transmission electron microscope to identify the precipitated minerals phases. A mixture of tochilinite and cronstedtite, as well as their separate phases, were identified on the surfaces of precursor minerals after one week under these experimental conditions. We are extending these experiments to conditions at -30°C using nanoparticulate olivine to further assess cryo-alteration processes.

References

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