Mineralogy and noble gas composition in experimentally altered Ningqiang carbonaceous chondrite

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At the early solar system, there would be abundant water in asteroids, and then, aqueous alteration could have commonly occurred. Aqueous alteration is thought to be the earliest chemical reaction in hydrous asteroids because of the lower reaction temperatures than those of thermal metamorphism. In order to elucidate the history of materials in the early solar system, it is important to know the effects of aqueous alteration on materials in primitive asteroids.

Carbonaceous chondrites are one of the most primitive materials in the solar system and contain large amounts of volatile elements such as noble gases. Q gas, one of the components of primordial noble gases and trapped in carbonaceous material called phase Q, is contained commonly in carbonaceous chondrites. Varieties of mineralogy and noble gas contents in chondrites inferred from the different extents of aqueous alteration experienced in parent bodies. Ar-rich gas, so-called subsolar gas, has Ar/Xe and Kr/Xe ratios higher than Q gas and is contained in some anhydrous carbonaceous chondrites. In contrast, carbonaceous chondrites that suffered extensive aqueous alteration are absent in Ar-rich gas. It would be expected that Ar-rich gas had been released during aqueous alteration. Nakamura et al. (2003) reported that the Ar-rich gas in Ningqiang was removed by light acid etching, accompanied by loss of amorphous rims around fine-grained silicates. This result suggested that Ar-rich gas is located in the amorphous rims. In contrast to the light acid etching, experimental aqueous alteration by neutral water performed in this study is more suitable to reproduce the condition of hydrous asteroids. Powdered Ningqiang sample were kept at 200 degree Celsius together with neutral liquid water for 0.5, 1, 2, 5, 10 and 20 days. The natural and altered samples were analyzed for mineralogy and noble gas compositions.

Mineralogical analyses show that the natural Ningqiang consists of olivine, low-Ca pyroxene, magnetite, and iron sulfide. In the altered samples, olivine, low-Ca pyroxene and iron sulfide were decomposed and serpentine and hematite were newly formed. The ratio of serpentine / (olivine + pyroxene) increases from the 0.5-day to the 5-day, but remains constant after 5 days, indicating that major portion of serpentine was formed within the 5-day alteration.

Experimental aqueous alteration drastically changed noble gas composition in Ningqiang. 84%, 73%, and 70% of Ar, Kr and Xe, respectively, were removed from natural Ningqiang during only the 5-day alteration, while the losses of He and Ne were 42% and 41%, respectively. The Ar/Xe and Kr/Xe ratios of the noble gases remained in the altered samples fall gradually forward to those of Q gas from natural to 5-day samples, indicating that Q gas was remained in the altered samples. The calculated elemental ratios of the noble gases lost from samples are higher than those of the natural Ningqiang, suggesting that the noble gases removed during the alteration are enriched in Ar-rich gas. These results suggest that the carrier phases of Ar-rich gas is much susceptible to aqueous alteration than phase Q. Cosmogenic 21Ne was evenly distributed in olivine and pyroxene grains, and then 21Ne concentrations in the altered samples could be a measure of the extent of the aqueous alteration. As the alteration proceeds, the concentrations of primordial noble gases decrease steeply while that of 21Ne decreases slowly, suggesting that even low degrees of aqueous alteration removes great amounts of primordial noble gases. As well as primordial noble gases, almost all of radiogenic 129Xe, which is generated by the beta decay of 129I, was lost by the 10-day alteration. This result suggests that not only thermal metamorphism but also aqueous alteration could reset radiometric ages, and hence the 129I-129Xe age of hydrous chondrites would reflect the timing when the aqueous alteration has finished in hydrous asteroids.