Hydrothermal experiments of anorthite with implications for Na-metasomatism on carbonaceous chondrite parent body

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In CO/CV chondrites, nepheline and sodalite are widely distributed in the chondrule mesostases, the Ca, Al-rich inclusions (CAIs), and the matrices. Many petrographic studies have shown abundant evidence suggesting that the nepheline and sodalite are secondary phases altered from plagioclase and/or melilite by a chemical reaction with Na-rich fluids (Na-metasomatism) occurred in the chondrite parent bodies (Kojima et al., 1996; Russell et al., 1998; Krot et al., 1998; Tomeoka and Itoh, 2004). Recently, Ichimura et al. (2017) carried out of hydrothermal experiments of gehlenite (Al-rich melilite) and plagioclase (An48). The results revealed that gehlenite and plagioclase are easily altered to zeolitic materials (fabriesite, hydroxycancrinite, analcime) at 200 °C for 168 h using solutions of pH 0, 7, 13, and 14 with a uniform Na^+ concentration (1 mol/L). From differential thermal analysis of these zeolites, they concluded that those zeolitic materials are capable of transforming to nepheline by heating in meteorite parent bodies. However, it is known that chemical composition of plagioclase in actual chondrites is almost pure anorthite, not intermediate composition. Moreover, pH conditions in the experiments made by Ichimura et al. (2017) seems to be rather discrete. In the present study, we performed a number of hydrothermal experiments using An95 with solutions of various pH and Na^+ concentration, and made crystal identifications, micro-textural observations, chemical analyses. The purpose of this study is constraint of environment in carbonaceous chondrite parent bodies by revealing process of nephelinization.

We used natural, An-rich plagioclase (An95) as a starting material. The reaction solution of pH 0, 7, 8.5, 10, 11.5, 13 and 14 were prepared for the hydrothermal experiments with different water/rock (W/R) ratios (46.7 ml/g). Na^+ concentration in solutions is maintained at 1, 3 and 5.5 mol/l by addition of NaCl (thereby high Na^+ concentration means high Cl^- concentration). Hydrothermal alteration experiments were performed with a PTFE reaction vessel loaded into steel autoclave at 200 °C and 1.5 MPa for run duration time of 168 hours. The recovered samples from the hydrothermal experiments separated from residual liquids and dried in an oven at 60 °C for 12 h, and then analyzed by XRD, SEM, and TEM.

As results of experiments using Na^+ = 1 mol/L solutions, no secondary phase was observed under pH 11.5, while sodalite and hydroxycancrinite were formed as secondary phases at pH 13. Moreover, fabriesite and hydroxycancrinite were formed at pH 14. In the case of Na^+ = 3 and 5.5 mol/L, large amounts of secondary phases (mainly sodalite) were formed over pH 11.5 condition. Considering of the previous (Ichimura et al., 2017) and present results, we can conclude the following three point: (1) Anorthite-rich plagioclase (low Si/Al ratio) are favorably altered into zeolites with low Si/Al ratio (e.g., sodalite, fabriesite and hydroxycancrinite) rather those with high Si/Al ratio (e.g., analcime). (2) With increasing solution pH, Si/Al ratio in the secondary phase becomes low. (3) Using Na^+ and Cl^- concentration in solution, significant amounts of secondary phases were formed even under moderate alkaline condition.

References

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