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High-pressure phase relations in NaAl3Si3O11-CaAl4Si2O11 system with application to Na-rich CAS in shocked meteorites

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CAS phase with CaAl4Si2O11 composition is a high-pressure aluminosilicate with a hexagonal Ba-ferrite structure. Recent high pressure experiments indicated that the CaAl4Si2O11-rich CAS phase is one of high-pressure phases of materials consisting of continental crust, sediments, and basaltic crust. Based on the experiments, it is suggested that CAS phase is stable at depths of the transition zone and the uppermost lower mantle (Akaogi et al., 2009). Beck et al. (2004) found CAS phase with high Na content (Na:Ca ratio of 3:1) in the NaAl3Si3O11-CaAl4Si2O11 system in shocked Martian meteorites. However, the Na-rich CAS phase has never been synthesized by high -pressure experiments, and therefore the stability field of the Na-Ca CAS solid solution has not yet been clarified. In this study, we have examined high pressure phase relations in the system NaAl3 Si3O11-CaAl4Si2O11 to determine the stability field of CAS phase, and have applied the results to evaluate P,T conditions at which the natural Na-rich CAS phase occurred.
The high-pressure phase relations in the system were examined at 13-23 GPa and 1600-1900 C, using a multianvil apparatus. At 1600 C, CaAl4Si2O11 CAS phase is stable above about 13 GPa. In the system NaAl3Si3O11-CaAl4Si2O11, the solubility of NaAl3Si3O11 component in the CAS solid solution increases with increasing pressure. The CAS phase coexists with jadeite, corundum and stishovite below 22 GPa. Above 22 GPa, the CAS phase coexists with calcium ferrite, corundum and stishovite. At 1600 C, maximum solubility of NaAl3Si3O11 component is about 50 mol% at about 22 GPa, above which the solubility decreases with pressure. The maximum solubility of NaAl3Si3O11 component increases with temperature to around 65 mol % at 1900 C. It is suggested that the maximum solubility is about 80 mol% at 2200 C. Lattice parameters of the CAS phase change with increase of the NaAl3Si3O11 component: a-axis decreases and c-axis slightly increases, resulting in decrease of molar volume.
Based on the above phase relations, we conclude that the natural Na-rich CAS phase in the shocked Martian meteorites crystallized at pressure around 22 GPa and temperature close to or higher than 2000-2200 C. The estimated P, T conditions are consistent with those evaluated using other high-pressure minerals such as K-hollandite and majorite-magnesiowustite assemblage found in the shocked meteorites.

Keywords: high-pressure phase relation, CAS phase, martian meteorite, shock metamorphism