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Brearleyite, $Ca_{12}Al_{14}O_{32}Cl_2$, a new alteration mineral from the NWA 1934 meteorite

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Abstract

Brearleyite (IMA 2010-062, $Ca_{12}Al_{14}O_{32}Cl_2$) is a Cl-bearing mayenite, occurring as fine-grained aggregates coexisting with hercynite, gehlenite, and perovskite in a rare krotite ($CaAl_2O_4$) dominant refractory inclusion from the Northwest Africa 1934 CV3 carbonaceous chondrite. The phase was characterized by SEM, TEM-SAED, micro-Raman, and EPMA. The mean chemical composition of the brearleyite is (wt%) Al_2O_3 48.48, CaO 45.73, Cl 5.12, FeO 0.80, Na_2O 0.12, TiO_2 0.03, –O 1.16, sum 99.12. The corresponding empirical formula calculated on the basis of 34 O+Cl atoms is $(Ca_{11.91}Na_{0.06})_{\Sigma 11.97}(Al_{13.89}Fe_{0.16}Ti_{0.01})_{\Sigma 14.06}O_{31.89}Cl_{2.11}$. The Raman spectrum of brealryeite indicates very close structural similarity to synthetic $Ca_{12}Al_{14}O_{32}Cl_2$. Rietveld refinement of an integrated TEM-SAED ring pattern from a FIB section quantifies this structural relationship and indicates that brearleyite is cubic, $I\bar{4}3d$; a = 11.98(8) Å, V = 1719.1(2) Å^3, and Z = 2. It has a framework structure in which AlO_4 tetrahedra share corners to form eight-membered rings. Within this framework, the Cl atom is located at a special position (3/8,0,1/4) with 0.4(2) occupancy and Ca appears to be disordered on two partially occupied sites similar to synthetic Cl-mayenite. Brearleyite has a light olive color under diffuse reflected light and a calculated density of 2.797 g/cm^3. Brearleyite is not only a new meteoritic Ca-,Al-phase, but also a new meteoritic Cl-rich phase. It likely formed by the reaction of krotite with Cl-bearing hot gases or fluids.

Keywords: Brearleyite, $Ca_{12}Al_{14}O_{32}Cl_2$, new mineral, Cl-bearing mayenite, NWA 1934 meteorite, CV3 carbonaceous chondrite, SAED ring pattern, Rietveld refinement