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Kenorozhdestvenskayaite-(Fe), $Ag_6(Ag_4Fe_2)Sb_4S_{12}\square$: A new tetrahedrite group mineral containing a natural $[Ag_6]^{4+}$ cluster and its relationship to the synthetic ternary phosphide $(Ag_6M_4P_{12})M'_6$

Kai Qu[1,2,*], Weizhi Sun[3], Fabrizio Nestola[4,†], Xiangping Gu[5], Zeqiang Yang[3], Xianzhang Sima[2], Chao Tang[2], Guang Fan[6], and Yanjuan Wang[4,7,*]

[1]School of Earth Sciences and Engineering, Nanjing University, Nanjing 210023, China
[2]Tianjin Center, China Geological Survey, Tianjin 300170, China
[3]No. 3 Institute of Geological and Mineral Resources Survey of Henan Geological Bureau, Xinyang 464000, China
[4]Department of Geosciences, University of Padova, Padova 35131, Italy
[5]School of Geosciences and Info-Physics, Central South University, Changsha 410012, Hunan, China
[6]Beijing Research Institute of Uranium Geology, Beijing 100029, China
[7]School of Earth Sciences and Resources, China University of Geosciences (Beijing), Beijing 100083, China

Abstract

$[Ag_6]^{4+}$ clusters are extremely rare in nature (only found in Ag-rich tetrahedrite group minerals). Due to their remarkable structures and some promising applications, a few synthesis phases that contain octahedral $[Ag_6]^{4+}$ clusters have been reported. However, the kinds of natural conditions that promote the formation of subvalent hexasilver clusters in tetrahedrite group minerals are still unclear. Kenorozhdestvenskayaite-(Fe), ideally $Ag_6(Ag_4Fe_2)Sb_4S_{12}\square$ is a new tetrahedrite group mineral containing a natural $[Ag_6]^{4+}$ cluster, found in the Yindongpo gold deposit, Weishancheng ore field, Henan Province, China. This new species occurs at the edges of galena crystals as anhedral grains of 2 to 20 μm in size and is associated with pyrargyrite, pyrrhotite, and siderite. Kenorozhdestvenskayaite-(Fe) is black in color with metallic luster. It is brittle with conchoidal fracture and has a calculated density of 5.329 g/cm^3. The empirical formula calculated on the basis of cation = 16 apfu is $^{M(2)}Ag_6\,{}^{M(1)}(Ag_{2.41}Cu_{1.20}Fe_{1.84}Zn_{0.71})_{\Sigma 6.16}\,{}^{X(3)}(Sb_{3.82}As_{0.01})_{\Sigma 3.83}\,{}^{S(1)}S_{11.60}\,{}^{S(2)}\square$. It is cubic, with space group $I\bar{4}3m$, a = 10.7119(6) Å, V = 1229.1(2) Å^3, and Z = 2. Since kenorozhdestvenskayaite-(Fe) is a new tetrahedrite group mineral containing a natural $[Ag_6]^{4+}$ cluster, its structure is comparable to the synthetic ternary phosphide $(Ag_6M_4P_{12})M'_6$. The presence of the unusual mineral assemblages, i.e., pyrrhotite and pyrargyrite, as well as the other keno-end-member tetrahedrites, indicates a low-f_{S_2} state for the mineralization stage, probably a result of the fluid boiling process in an open system that likely contributed to the formation of S-deficient tetrahedrites.

Keywords: Kenorozhdestvenskayaite-(Fe), silver cluster, $[Ag_6]^{4+}$ cluster, new mineral, tetrahedrite group, Yindongpo deposit