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Hazenite, $KNaMg_2(PO_4)_2 \cdot 14H_2O$, a new biologically related phosphate mineral, from Mono Lake, California, U.S.A.

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Abstract

A new biologically related, struvite-type phosphate mineral, hazenite, ideally $KNaMg_2(PO_4)_2 \cdot 14H_2O$, has been found in and/or on completely dried-out or decomposed cyanobacteria on porous calcium-carbonate (mainly calcite and aragonite) substrates in Mono Lake, California. The mineral occurs as radiating clusters of prismatic crystals and is colorless, transparent with white streak and vitreous luster. It is brittle, with the Mohs hardness of 2~2.5; cleavage is good on {001} and no twinning was observed. The measured and calculated densities are 1.91(3) and 1.88(2) g/cm^3, respectively. Hazenite is biaxial (+), with n_α =1.494(1), n_β = 1.498(1), n_γ = 1.503(1), $2V_{meas}$ = 41(2)°, $2V_{calc}$ = 42°, $X = b$, $Y = c$, $Z = a$, and does not fluoresce under long- or short-wave ultraviolet rays. The dispersion is strong with $r < v$. It is soluble in water. The electron microprobe analysis yielded an empirical formula of $K_{0.97}(Na_{0.96}Ca_{0.02})Mg_{2.07}[(P_{0.98}S_{0.02})O_4]_2 \cdot 13.90H_2O$. Hazenite is orthorhombic with space group *Pmnb* and unit-cell parameters a = 6.9349(4) Å, b = 25.174(2) Å, c = 11.2195(8) Å, and V = 1958.7(3) Å^3. There are many structural similarities between hazenite and struvite, as also revealed by their Raman spectra. The hazenite structure contains six symmetrically independent non-hydrogen cation sites, two for Mg^{2+} (Mg1 and Mg2), two for P^{5+} (P1 and P2), one for Na^+, and one for K^+. It can be viewed as three types of layers stacking along the **b**-axis, in a repeating sequence of ABCBABCB…, where layer A consists of $Mg1(H_2O)_6$ octahedra and NaO_6 trigonal prisms, layer B of $P1O_4$ and $P2O_4$ tetrahedra, and layer C of $Mg2(H_2O)_6$ octahedra and very irregular KO_6 polyhedra. These layers are linked together by hydrogen bonds, plus the K-O bonds between layers B and C (K-O5-P2). Interestingly, the combination of layers B and C in hazenite exhibits a configuration analogous to the struvite-(K) structure. Hazenite is believed to form in high pH environments through the involvement of cyanobacterial activities. To our knowledge, hazenite is the first struvite-type compound that contains two structurally distinct monovalent cations (K and Na), pointing to an exclusive role of biological activity in the mineralization process.

Keywords: Hazenite, struvite-type materials, phosphates, biomineral, crystal structure, X-ray diffraction, Raman spectra