

# Zhanghuifenite, $\text{Na}_3\text{Mn}_4^{2+}\text{Mg}_2\text{Al}(\text{PO}_4)_6$ , a new mineral isostructural with bobfergusonite, from the Santa Ana mine, San Luis province, Argentina

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## ABSTRACT

A new mineral species, zhanghuifenite, ideally  $\text{Na}_3\text{Mn}_4^{2+}\text{Mg}_2\text{Al}(\text{PO}_4)_6$ , has been found in the Santa Ana mine, San Luis province, Argentina. It occurs in irregular veinlets or patches, 5 mm thick, in a nodule of beusite interlaminated with lithiophilite. Broken pieces of zhanghuifenite are blocky or tabular. Single crystals are up to  $0.8 \times 0.5 \times 0.5$  mm. No twinning or parting is observed macroscopically. The mineral is deep green, transparent with pale green streak and vitreous luster. It is brittle and has a Mohs hardness of ~5 with good cleavage on {010}. The measured and calculated densities are 3.63(2) and 3.62 g/cm<sup>3</sup>, respectively. Optically, zhanghuifenite is biaxial (+), with  $\alpha = 1.675(2)$ ,  $\beta = 1.680(2)$ ,  $\gamma = 1.690(2)$  (white light),  $2V$  (meas) = 74(2)°, and  $2V$  (calc) = 71°. The calculated compatibility index based on the empirical formula is 0.020 (excellent). An electron microprobe analysis yields an empirical formula (based on 24 O apfu)  $(\text{Na}_{2.80}\text{Ca}_{0.11})_{\Sigma 2.91}(\text{Mn}_{3.09}\text{Fe}_{0.47}^{2+}\text{Mg}_{0.36})_{\Sigma 3.92}(\text{Mg}_{1.31}\text{Fe}_{0.69}^{2+})_{\Sigma 2.00}(\text{Al}_{0.81}\text{Fe}_{0.19}^{3+})(\text{PO}_4)_6$ . Zhanghuifenite is insoluble in water or hydrochloric acid.

Zhanghuifenite is isostructural with bobfergusonite, a member of the alluaudite supergroup. It is monoclinic, with space group  $P2_1/n$ ,  $Z = 4$ , and unit-cell parameters  $a = 12.8926(3)$ ,  $b = 12.4658(3)$ ,  $c = 10.9178(2)$  Å,  $\beta = 97.9200(10)^\circ$ , and  $V = 1737.93(7)$  Å<sup>3</sup>. The crystal structure of zhanghuifenite contains six octahedral  $M$  (= Mn, Fe, Mg, Al) sites and five  $X$  (= Na, Mn, Ca) sites with coordination numbers between 6 and 8. The six  $M$  octahedra share edges to form two types of kinked chains extending along [101], with one consisting of  $M1$ - $M4$ - $M5$  and the other  $M2$ - $M3$ - $M6$ . These chains are joined by  $\text{PO}_4$  tetrahedra to form sheets parallel to (010), which are linked together through corner-sharing between  $\text{PO}_4$  tetrahedra and  $\text{MO}_6$  octahedra in the adjacent sheets, leaving open channels parallel to  $a$ , where the large  $X$  cations are situated. Zhanghuifenite differs from bobfergusonite in two major aspects. One is that the  $M4$  and  $M5$  sites in the former are mainly occupied by Mg, but by  $\text{Fe}^{2+}$  and  $\text{Fe}^{3+}$ , respectively, in the latter. The other is that the  $X2$ - $X5$  sites in zhanghuifenite are all nearly or fully filled with Na, resulting in 3 Na apfu in the ideal formula, but  $X4$  and  $X5$  are merely half-occupied in bobfergusonite, giving rise to 2 Na apfu.

**Keywords:** Zhanghuifenite, wyllieite, alluaudite, crystal structure, X-ray diffraction, Raman spectra