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## LETTER

# Synthesis and crystal structure of V-rich tourmaline

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## ABSTRACT

Tourmaline is the most abundant natural borosilicate, an important indicator of its host rock chemistry and formation conditions, as well as a valuable material for various industrial applications. In this work, V-rich tourmaline crystals were grown ($T = 650$ °C, $P = 100$ MPa) for the first time in two systems: (V1) $V_2O_3$–$Al_2O_3$–$SiO_2$–$B_2O_3$–$H_2O$ and (V2) $Na_2O$–MgO–$V_2O_3$–$Al_2O_3$–$SiO_2$–$B_2O_3$–$H_2O$. Newly formed overgrowth layers of tourmaline on an elbaite seed are dark green, up to 0.7 mm in thickness, and contain up to ~12 wt% $V_2O_3$ [~1.6 atoms per formula unit (apfu)] and ~41 wt% $V_2O_3$ (~6 apfu) for the system V1 and V2, respectively. Synthetic tourmalines V1 [$a = 7.0988(1)$, $b = 9.4274(2)$, $c = 9.4279(2)$ Å, $\alpha = 113.920(2)°$, $\beta = 104.551(2)°$, $\gamma = 104.515(2)°$] and V2 [$a = 7.3390(1)$, $b = 9.6075(2)$, $c = 9.6077(2)$ Å, $\alpha = 113.742(2)°$, $\beta = 104.721(2)°$, $\gamma = 104.786(2)°$] are triclinic ($P1$) due to cation ordering and could be considered as dimorphs of the V-dominant analog of alumino-oxy-rossmanite (V1) and oxy-vanadium-dravite (V2). Formation of V-rich tourmalines does not require high temperatures or pressures and is constrained by the simultaneous abundance of boron and vanadium in the mineral-forming medium. The stability of the crystal structure of V-rich tourmaline is increased by the incorporation of Mg cations, thereby reducing the disproportion of the octahedra in V,Al-rich species.

**Keywords:** Tourmaline, vanadium, synthesis, single-crystal X-ray diffraction