Crystal chemistry of synthetic Ca$_2$Al$_3$Si$_3$O$_{12}$OH–Sr$_2$Al$_3$Si$_3$O$_{12}$OH solid-solution series of zoisite and clinozoisite

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ABSTRACT

Coexisting solid-solution series of synthetic zoisite-(Sr) and clinozoisite-(Sr) were synthesized in a 1 M (Ca,Sr)Cl$_2$ solution at 2.0 GPa, 600 °C for 6 days in a piston cylinder press. Solid solutions were synthesized from $X_{Sr}^{Zo}$ = Sr/(Ca + Sr) = 0.06 to 1 and $X_{Sr}^{Czo}$ = 0.08 to 0.5 in zoisite and clinozoisite, respectively. The products were characterized with SEM, EMP, and powder-XRD. Zoisites form crystals up to 30 μm in size. Lattice parameters of zoisite increase linearly with increasing Sr content. For synthetic zoisite-(Sr) lattice parameters are $a = 16.3567(5)$ Å, $b = 5.5992(2)$ Å, $c = 10.2612(5)$ Å, and $V = 939.78(7)$ Å$^3$ in space group $Pnma$. Volume of clinozoisite ($P2_1/c/m$) increases with increasing $X_{Sr}^{Czo}$ but the lattice parameter $a$ collapses, and $b$, $c$, and $β$ have a discontinuity at $X_{Sr}^{Czo} ≈ 0.25$. The decrease in angle $β$ of clinozoisite results in compression of M3 and T3 polyhedra and increase of the A2 polyhedron. A1-O7 distance of 2.12 Å in clinozoisite is extremely short at $X_{Sr}^{Czo} ≈ 0.25$. The further Sr incorporation on A2 this distance relaxes quickly to 2.24 Å, combined with a torsion of T3. In zoisite, Sr incorporation leads to an opposite movement of neighboring octahedral chains parallel $a$ and causes changes in the linked T3, and angle O5-T3-O6 increases with $X_{Sr}^{Zo}$ from 96.3° to 101°. The intra-crystalline distribution of Sr shows that A2 is the favored position and continuous incorporation on A1-position starts above $X_{Sr}^{Zo} ≈ 0.35$ for zoisite and above $X_{Sr}^{Czo} ≈ 0.45$ for clinozoisite.

Keywords: Zoisite, clinozoisite, strontium, synthesis, solid-solution series, hydrothermal, EMP data, XRD data

INTRODUCTION

Minerals of the epidote and lawsonite group are main constituents in metasites and important carriers of trace elements such as Sr, Pb, and the rare earth elements. In mafic lawsonite blueschist more than 75% of the whole-rock Sr is located in lawsonite, and in eclogite about 99% in epidote minerals (Spandler et al. 2003). The element budget of Sr high-pressure rocks is therefore strongly controlled by these minerals.

During subduction of a metamorphosed oceanic crust, lawsonite and epidote minerals, which carry water into the deep subduction zone, will eventually dehydrate. To understand the role of Sr in the subduction process the distribution coefficients (D$^{met/hyd}$) are needed (Zack et al. 2002). The partitioning is generally controlled by pressure, temperature and bulk composition, i.e., a specific paragenesis. Brastad (1984) for example described Sr-metasomatism in an eclogite and partitioning of Sr between zoisite and clinozoisite, with a SrO-content of up to 7.4 wt% in clinozoisite. The importance of the epidote minerals as a carrier of Sr is underlined by the recent studies of Giuli et al. (1999) report Al-Fe disorder on M-sites in synthetic epidotes, and the study of Nagashima and Akasaka (2004) shows structural changes in the synthetic piemontite-clinozoisite solid-