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Composition of synthetic tremolite-tschermakite solid solutions in amphibole + anorthite- and amphibole + zoisite-bearing assemblages

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ABSTRACT

The composition of synthetic amphiboles was investigated experimentally along the tremolite-tschermakite join in the system CaO-MgO-Al_2O_3-SiO_2-H_2O-Br_2. Compositions of these amphiboles were studied within the phase assemblages: amphibole-anorthite-quartz-diopside (I), amphibole-anorthite-quartz-talc (II), amphibole-anorthite-quartz-enstatite (III), amphibole-anorthite-talc-clinochlore (IV), amphibole-zoisite-talc-quartz (V), and amphibole-zoisite-talc-clinochlore (VI). Assemblages were synthesized from oxide-hydroxide mixtures in the presence of a $CaBr_2$-bearing solution between 600–800 °C and 200–2000 MPa. Solid phases were investigated using SEM, HRTEM, EMP, and XRD techniques. EMP data show that the amphiboles produced are solid solutions of the ternary system tremolite-tschermakite-cummingtonite. Enstatite, diopside, talc, and clinochlore showed small deviations from their respective end-member compositions due to incorporation of some Al.

The thermodynamic properties of the tschermakite end-member and the mixing properties along the tremolite-tschermakite join were extracted from corresponding exchange reactions of the unreversed synthesized phase assemblages I–VI. Various ideal mixing models were tested for Al-Mg and Al-Si substitution at octahedral M2 and M3 sites and at tetrahedral T1-sites. Best fits were obtained for a two-site coupled model, resulting in $\Delta_f H^0_{ts} = -12528.3 \pm 11.7$ kJ/mol and $S^0_{ts} = 556.5 \pm 12.0$ J/(mol·K) for the tschermakite end-member. Similar calculations were carried out for magnesiohornblende, and values of $\Delta_f H^0_{Mghb} = -12418.7 \pm 5.9$ kJ/mol and $S^0_{Mghb} = 562.8 \pm 6.1$ J/(mol·K) were extracted. Calculated phase relations and amphibole compositions agree well with experimental data if the derived thermodynamic data of tschermakite and a two-site mixing model for Al incorporation in amphibole solid solutions are applied.