

Stability of hydrothermal tourmaline: insights from phase equilibria experiments in the system MgO-(±FeO)-Al₂O₃-SiO₂-H₂O-NaCl-B₂O₃ at 400-650 °C and 3 kbar

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Tourmaline occurs in a wide range of magmatic, metamorphic and hydrothermal environments, including granite-related magmatic-hydrothermal systems, granitic pegmatites, boron-rich metasediments and orogenic gold deposits. Naturally occurring tourmaline shows wide variations in major element composition, reflecting many cationic and anionic crystal-chemical substitutions. The potential of tourmaline as a petrogenetic indicator has been widely recognized, but quantitative modeling of natural tourmaline compositions is not yet possible due to the lack of reliable thermodynamic data for its end-members and insufficient experimental data for tourmaline phase equilibria. The stability of tourmalines has been addressed by experimental and geochemical modeling techniques, but phase equilibria studies involving Mg-Fe tourmaline solid-solutions have proven highly challenging.

We report the preliminary results of experimental phase equilibria studies in the system MgO-(±FeO)-Al₂O₃-SiO₂-H₂O-NaCl-B₂O₃ the temperature range 400-650 °C and at a pressure of 3.0 kbar. The experiments used natural quartz, H₂O, NaCl, H₃BO₃ and oxide powders as starting materials and experiments were performed in gold capsules in cold-seal pressure vessels. Two series of experiments were performed, which are experiments in the pure Mg system and experiments along the Mg-Fe binary. The experiments in the Mg system were designed to investigate the Tschermak (Al-for-Si) exchange and to link the stability of tourmaline with that of coexisting Mg-chlorite. The experiments in the Mg-Fe system were designed to constrain the stability of tourmaline solid-solutions along the dravite-schorl binary and to yield Mg-Fe partitioning data between coexisting tourmaline and chlorite solid-solutions. The experimental results make it possible to construct the tourmaline phase equilibria in the Mg and Mg-Fe systems. The data show clear temperature dependence of the extent of Tschermak substitution in the Mg system and of the Fe-for-Mg exchange in the Mg-Fe system. The new data will be used, in conjunction with experimental data from the literature and calorimetric data, to derive thermodynamic properties of key tourmaline end-members.