Compression and Metastability of the Amphibole Tremolite to High Pressures and Temperatures through Raman Spectroscopy

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Abstract:

Hydrated minerals in oceanic lithosphere play an important role in subduction zones as they can contribute significantly to the transport of water to the deep lithosphere and convective upper mantle where dehydration reactions make the water available for metasomatic processes and flux melting in the overlying mantle wedge. A significant portion of the water stored in the oceanic crust and depleted mantle is in the form of hydroxyl units in amphibole minerals, which are up to 2 weight percent water. In this study, we investigate the high-pressure and temperature behavior of tremolite, a calcic amphibole with the end member composition [ ]$Ca_2Mg_5Si_8O_{22}(OH)_2$. Raman spectroscopy is used to characterize tremolite at pressures to 49 GPa at room temperature over multiple runs using a symmetric type diamond anvil cell with methanol-ethanol-water and neon as pressure transmitting media, and at temperatures up to 600 K at ambient pressure with an experimental focus on the bonding environment of the hydroxyl unit and the calcium and magnesium cation environments. The behavior of the hydroxyl stretching vibration is concordant with previous infrared spectroscopic results, implying that the role of Davydov splitting in the amphibole structure is small. Moreover, as with the range of other hydroxyl-bearing minerals, the hydroxyl librations have slightly negative mode shifts. After background removal and peak assignment of spectra, the peak shifts of ~16 modes with increasing pressure and increasing temperature are each fit to second degree polynomials and the results are used to determine the isothermal and isobaric mode-Grüneisen parameters (γ_{iT} and γ_{iP}) respectively. An analysis is conducted of the shifts of the vibrational modes and changes in peak character, intensity, and number of modes present with increasing pressure for samples in the different pressure transmitting media to assess possible structural symmetry changes in tremolite under compression. Our work provides constraints and guidance for future work on the metastability of amphiboles in subduction zones and the upper mantle, and on the intrinsic crystallographic stability of the monoclinic amphibole structure.