Phase evolutions of hydrous orthoenstatite at high pressures and temperatures

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Pyroxenes, including Mg-rich orthopyroxene and Ca-rich clinopyroxene, are believed to be among the most important minerals in the Earth's upper mantle (account for ~20% by volume). Pyroxenes are major phases of harzburgite and lherzolite, which are important components subducting slabs, so the high pressure behaviors of pyroxenes should influence the physical properties of the subduction slabs. Therefore, understanding the thermal equations of state and phase evolutions of pyroxenes with elevated pressure and temperature is crucial to model the upper mantle and subduction zones. On the other hand, water is expected to be incorporated into pyroxene minerals at upper mantle environments, yet the effect of water on the high pressure behaviors of pyroxene has not been fully explored. In this study, we synthesized two orthoenstatite ($MgSiO_3$) with different water contents using a multi-anvil high pressure apparatus at the Institute of Geochemistry, Chinese Academy of Sciences. In situ high-pressure single crystal diffraction experiments on orthoenstatite were performed up to 30 GPa at the experimental station 13BMC of the Advanced Photon Source. Both samples underwent two phase transitions at 12-14 GPa (β-phase, $P2_1/c$) and 28-29 GPa (a monoclinic phase) at ambient temperature. High-pressure, high-temperature single crystal diffraction experiments were performed up to ~20 GPa and 700 K. At 500 K, both samples transformed to the β-phase at 12-14 GPa, and the β-phases sustained up to ~20 GPa and 700 K. From the experimental data, we derived the thermal parameters of the samples, and we performed structural refinements of orthoenstatite at high pressures and temperatures. Our results suggest that hydrous orthoenstatite might survive as the β-phase to the depth of transition zone under certain subduction P-T conditions, and water incorporated in its structure could also be transported into the depth of mantle transition zone.