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Phase transformation of ferric-iron-rich silicate in Earth's mid-mantle

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Abstract

The incorporation of ferric iron in mantle silicates stabilizes different crystal structures and changes phase transition conditions, thus impacting seismic wave speeds and discontinuities. Recent experiments of $MgSiO_3$-Fe_2O_3 mixtures indicate the coexistence of fully oxidized iron-rich $(Mg_{0.5}Fe^{3+}_{0.5})(Fe^{3+}_{0.5}Si_{0.5})O_3$ with Fe-poor silicate (wadsleyite or bridgmanite) and stishovite at 15 to 27 GPa and 1773 to 2000 K, conditions relevant to subducted lithosphere in the Earth's transition zone and uppermost lower mantle. X-ray diffraction (XRD) shows that $(Mg_{0.5}Fe^{3+}_{0.5})(Fe^{3+}_{0.5}Si_{0.5})O_3$ recovered from these conditions adopts the $R3c$ $LiNbO_3$-type structure, which transforms to the bridgmanite structure again between 18.3 and 24.7 GPa at 300 K. XRD data are used to obtain the equation of state of the $LiNbO_3$-type phase up to 18.3 GPa. Combined with multi-anvil experiments, these observations suggest that the stable phase of $(Mg_{0.5}Fe^{3+}_{0.5})(Fe^{3+}_{0.5}Si_{0.5})O_3$ is bridgmanite at 15–27 GPa, which transforms on decompression to $LiNbO_3$-type structure. Our calculation revealed that ordering of the ferric ion reduces the kinetic energy barrier of the transition between $(Mg_{0.5}Fe^{3+}_{0.5})(Fe^{3+}_{0.5}Si_{0.5})O_3$ $LiNbO_3$ structure and bridgmanite relative to the $MgSiO_3$ akimotoite-bridgmanite system. A dense Fe^{3+}-rich bridgmanite structure is thus stable at substantially shallower depths than $MgSiO_3$ bridgmanite and would promote subduction.

Keywords: $LiNbO_3$, bridgmanite, ferric iron, transition zone, lower mantle, phase transition, equation of state