Subsolidus phase transitions in $(Mg,Fe)_2SiO_4$ at transition zone conditions

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Knowledge of phase transitions in $(Mg,Fe)_2SiO_4$ is important to a detailed understanding of the constitution and evolution of Earth's mantle. For example, the dissociation of $(Mg,Fe)_2SiO_4$ ringwoodite (rw) into $(Mg,Fe)SiO_3$ bridgmanite (bdg) + (Mg,Fe)O ferropericlase (fp) is thought to be responsible for the 660-km discontinuity detected globally from seismic observations [1]. On a local scale, high-velocity anomalies have been detected in 660-km tomographic images within upwelling plumes where temperatures are higher than those of the average mantle [2]. Higher temperatures would have been more ubiquitous in the early Earth's mantle, which may have affected the thermochemical evolution of the deep mantle in the past. To understand the nature of the transition zone within hot plumes or in a younger mantle, it is important to investigate the phase relations in $(Mg,Fe)_2SiO_4$ at mantle transition zone pressures and at higher temperatures than those of the average mantle. At these higher temperatures, ringwoodite is not stable, and wadsleyite (wd) transforms directly to bdg + fp. However, this wd → bdg + fp phase transition has not been the subject of much previous work [3] and its Clapeyron slope is poorly constrained [4]. Here, we report the Clapeyron slope of wd → bdg + fp based on four pairs of data points using synchrotron X-ray diffraction in a membrane-driven laser-heated diamond anvil cell, collected at ~22–23 GPa and 1900–2500 K. These new brackets suggest a Clapeyron slope of approximately +1.5 MPa/K, which is different from the slightly negative Clapeyron slope (–2 MPa/K) reported by Hirose (2002) [4]. Multiple brackets at different temperatures are required in order to tightly constrain the Clapeyron slope of a phase boundary, but the Clapeyron slope of Hirose (2002) [4] was inferred from only one pair of data points near the triple point at 2273 K. Changes in thermo-physical properties in the transition zone depend on the combined effects of multiple phase transitions, including this wd → bdg + fp phase transition at high temperatures, and these changes can affect mantle material circulation. However, all previous thermodynamic and geodynamic models considered this phase transition to have a negative Clapeyron slope. The effects of the sign and magnitude of this slope on the transition zone in a pyrolitic mantle remain to be explored computationally.

Reference:

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