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Fe^{2+}-Mg partitioning between garnet, magnesiowüstite, and $(Mg,Fe)_2SiO_4$ phases of the transition zone

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ABSTRACT

The partitioning of Fe and Mg between garnet coexisting with olivine, wadsleyite, ringwoodite and magnesiowüstite solid solutions has been measured between 9 and 19 GPa and 1400–1700 °C. In addition to studying exchange reactions involving the pyrope-almandine garnet solid solution, majoritic garnets forming in a natural peridotite bulk composition have been also examined. Metallic Fe was added to all bulk compositions to buffer the Fe^{3+} concentration at its lowest possible level. Partitioning data between pyrope-almandine garnet and ringwoodite were combined with data for garnet-magnesiowüstite and ringwoodite-magnesiowüstite partitioning to refine thermodynamic mixing properties for these solid solutions at 18 GPa and 1400 °C. A multiple non-linear regression employing cation exchange data between these 3 solid solutions yielded the following well-constrained values for the differences in symmetric solid-solution interaction parameters: $W^{mw}_{FeMg} - W^{ring}_{FeMg}$ = 8.8(2) kJ/mol, $W^{mw}_{FeMg} - W^{gt}_{FeMg}$ = 12.8(5) kJ/mol, $W^{ring}_{FeMg} - W^{gt}_{FeMg}$ = 4.0(4) kJ/mol.

These differences were then solved simultaneously to give, on a single site basis: W^{mw}_{FeMg} = 13.2(3) kJ/mol, W^{ring}_{FeMg} = 4.4(2) kJ/mol, W^{gt}_{FeMg} = 0.3(3) kJ/mol.

In a peridotite composition, the occurrence of majorite and grossular garnet components produced a measurable influence on the Fe-Mg partitioning, however, the combined effect was relatively small because each individual component affected the partitioning in an opposite direction. These data, combined with previously determined phase relations in the Mg_2SiO_4-Fe_2SiO_4 system, were used to calculate the influence of garnet Fe-Mg partitioning on the pressure intervals of divariant $(Mg,Fe)_2SiO_4$ phase transformations in the transition zone. Results show that the presence of garnet reduces the pressure interval over which the $(Mg_{0.9},Fe_{0.1})_2SiO_4$ olivine to wadsleyite transformation occurs in a peridotite composition to 0.35 GPa (10 km) in comparison to 0.5 GPa in a garnet-free system. This width, however, is still greater than the estimated width of 4 km for the 410 km discontinuity observed in some regions of the Earth as inferred from high frequency reflected and converted seismic waves. The existence of garnet in a peridotite composition in the mantle cannot, therefore, be the only explanation as to why the 410 km discontinuity is, in some regions of the Earth, apparently sharper than experimental estimates for the $(Mg_{0.9},Fe_{0.1})_2SiO_4$ olivine to wadsleyite transformation. The wadsleyite to ringwoodite transformation is reduced to 0.8 GPa (25 km) compared to 1 GPa in the garnet-free system.