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EQUATIONS OF STATE OF OLIVINE-TRANSFORMED SPINELS

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Based on our recent data on the elasticity of olivine in the forsterite-fayalite series, Birch's law for the velocity-density-mean atomic weight relation is used to construct the equations of state of spinels in the Mg_2SiO_4–Fe_2SiO_4 system. The equations of state of these olivine-transformed spinels are first presented and then discussed in relation to the equations of state of the same compositions in the olivine structure. Effects of the iron/magnesium ratios in these mineral systems on the solid equations of state are discussed. We conclude that (1) Birch's law is a useful scheme by which we can deduce equation-of-state parameters of the yet unmeasured olivine-transformed spinels; (2) the olivine-transformed spinels are less compressible than olivines at all pressures; (3) the β–Mg_2SiO_4 (spinel) is more compressible than the Fe_2SiO_4–spinel, although in the olivine structure fayalite was seen to be more compressible than forsterite; and (4) the incompressibility values for the olivine-transformed spinels are in the neighborhood of 2 Mb and their first pressure derivatives range from 4 to 5 as the iron/magnesium ratio in the lattice increases.

1. Introduction

The equations of state of solid phases in the Mg_2SiO_4–Fe_2SiO_4 system are of special interest in the study of the physics and chemistry of the earth's mantle. The transition region at a depth of about 350 km in the earth is characterized by an abrupt increase in seismic velocity. This seismic observation has been attributed to pressure-induced changes in the crystal structure of the mantle materials. Laboratory petrological studies at high pressures and high temperatures (see, for example, Ringwood [1] for a review) have shown that olivine, a major component of the mantle, transforms to a spinel type structure with a density increase of about 10%. D.L. Anderson [2] attributed the seismic velocity jump observed at about 400 km in the earth to this olivine-spinel phase change. A study of the equations of state of solid phases in these mineral systems is then essential in geophysics for a better understanding of the mechanical and thermal state of the mantle. The equations of state of olivines as functions of iron/magnesium ratios have been studied in an earlier paper [3]; the equations of state of olivine-transformed spinels in the $(Mg_xFe_{1-x})_2SiO_4$ series are presented in this communication as part of our continuing investigations.

Laboratory determination of sound velocities in the olivine-transformed spinels is not easy. The difficulty in the experiment is two fold: (1) one has to produce the olivine-transformed spinels in the sufficient quantity under high-pressure and high-temperature conditions and (2) one must be able to sinter the material in a dense form without converting it back to olivine (or, one must be able to grow the olivine-transformed spinel single-crystals large enough to make acoustic measurements on them).

The first part of this paper presents the elastic constants and the equation-of-state parameters of olivine-transformed spinels, deduced from the application of Birch's law, followed by a comparison of these equations of state with experimental compression data. Effects of iron/magnesium ratios on the equations of state for these mineral systems are then illustrated.