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EQUATIONS OF STATE OF OLIVINE-TRANSFORMED SPINELS

D.H. CHUNG

Department of Earth and Planetary Sciences,
Massachusetts Institute of Technology,
Cambridge, Mass. 02139, USA

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 $\beta-Mg_2SiO_4$ (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.