American Mineralogist, Volume 95, pages 1708–1716, 2010

The thermal equation of state of $FeTiO_3$ ilmenite based on in situ X-ray diffraction at high pressures and temperatures

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Abstract

We present in situ measurements of the unit-cell volume of a natural terrestrial ilmenite (Jagersfontein mine, South Africa) and a synthetic reduced ilmenite ($FeTiO_3$) at simultaneous high pressure and high temperature up to 16 GPa and 1273 K. Unit-cell volumes were determined using energy-dispersive synchrotron X-ray diffraction in a multi-anvil press. Mössbauer analyses show that the synthetic sample contained insignificant amounts of Fe^{3+} both before and after the experiment. Results were fit to Birch-Murnaghan thermal equations of state, which reproduce the experimental data to within 0.5 and 0.7 GPa for the synthetic and natural samples, respectively. At ambient conditions, the unit-cell volume of the natural sample [$V_0 = 314.75 \pm 0.23$ (1σ) Å^3] is significantly smaller than that of the synthetic sample [$V_0 = 319.12 \pm 0.26$ Å^3]. The difference can be attributed to the presence of impurities and Fe^{3+} in the natural sample. The 1 bar isothermal bulk moduli K_{T0} for the reduced ilmenite is slightly larger than for the natural ilmenite (181 ± 7 and 165 ± 6 GPa, respectively), with pressure derivatives $K_0' = 3 \pm 1$. Our results, combined with literature data, suggest that the unit-cell volume of reduced ilmenite is significantly larger than that of oxidized ilmenite, whereas their thermoelastic parameters are similar. Our data provide more appropriate input parameters for thermo-chemical models of lunar interior evolution, in which reduced ilmenite plays a critical role.

Keywords: Ilmenite, equation of state, X-ray diffraction, lunar magma ocean