Composition and seismic velocities for models of chemical differentiation of the Moon

V.A. Kronrod, O.L. Kuskov, T.M. Kronrod

Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, Moscow, Russia (va_kronrod @mail.ru)

We consider models of internal structure of the Moon with five layers including a crust, a three-layer silicate mantle, and a Fe–10 wt.% S-core (ρ=5.7 g cm^{-3}). The general methodology is to combine geophysical and geochemical constraints and thermodynamic approach, and to develop, on this joint basis, the self-consistent model of Moon, accounting for its chemical composition and internal structure. The mass and moment-of-inertia factor and the hypothesis of chemical differentiation of the Moon as a result of partial melting of initially homogeneous material (hypothetical magma ocean) are used to model the internal structure of the Moon for four first-order parameters: (1) the thickness of the crust, and upper and middle mantle; (2) bulk composition of the mantle; (3) core sizes and masses; (4) velocities and density in the upper, middle and lower mantle. The model thicknesses of a crust, upper and middle mantle are variable parameters. The Al_2O_3 content in the lunar crust (ρ=3.0 g cm^{-3}) varied between 25 and 30 wt%. The concentrations of major oxides for the entire mantle varied in the ranges 2 $\leq$ CaO and Al_2O_3 $\leq$ 8%,25 $\leq$ MgO $\leq$ 45%,40 $\leq$ SiO_2 $\leq$ 54%,6 $\leq$ FeO $\leq$ 20%. Thermodynamic modeling of phase relations and physical properties in the multicomponent mineral system CaO-FeO-MgO-Al_2O_3-$SiO_2$was used to develop a method for solving the inverse problem. For the computation of phase diagram for a given chemical composition we have used the method of minimization of the total Gibbs free energy. We determine the permissible ranges of bulk composition, mineralogy, velocities and density in the upper, middle and lower mantle as well as core sizes and masses. The solution of the inverse problem is based on the Monte Carlo method. The basic conclusion arising from this study is that the silicate Moon is chemically stratified and enriched in FeO ($\sim$10-12 wt%). The Al_2O_3content can vary in the range of 4-7 wt% for the bulk Moon. The thickness of the crust is found to be 50 km. The size of the Fe–10 wt.% S-core is 300-350 km in radius. Velocity and density distributions in the lunar mantle are discussed.

This research was supported by Russian Academy of Sciences under Program 25 and by RFBR grant (06-05-64308).