Internal structure and composition of Io with highly oxidized materials

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Since the building blocks of the Galilean satellites likely experience the chemical interaction with H2O in the circum-jovian nebula, they would have strongly oxidized composition in which most of Fe and S form oxides and sulfate rather than metal and sulfide. However, previous models of the internal structures of these satellites have neglected such highly oxidized constituents. Here we revisit the model of internal structure and composition of Io taking into account highly oxidized materials to construct a basis for the internal structure models for the other Galilean satellites.

Model: For the solar mixture of major rock-forming elements, the mineral combination has been calculated taking the content of O as a parameter. We take into account the elements which have abundance more than 1/1000 of Si in the solar abundance (Anders and Grevesse 1989) and form oxides, metal, or sulfide under the standard temperature and pressure. Phase changes of Fe and S associated with oxidation are given from the phase diagram of Fe-S-O system of 1200 K (Lewis 1982). FeO, MgO, and other elements are partitioned into minerals following the rule of the norm calculation for simplicity. Apatite, orthoclase, nepheline, anorthite, diopside, olivine, hypersthene and MgSO4 are partitioned to the mantle, and ilmenite, chromite, metallic iron, magnetite, troilite and hematite are to the core. The moment of inertia factor is calculated from their mass ratio and average densities.

Results: As O is gradually added into the system from the initial condition in which all Fe consists of Fe-FeS, the composition and moment of inertia factor of system change as follows:

1) At first, metallic Fe becomes oxidized to FeO with the increase of total O in the system. FeO is partitioned into the mantle with forming olivine, therefore the average density of whole system decreases remarkably and the moment of inertia factor increases through this change.

2) After the consumption of metallic Fe, FeS is continuously oxidized with forming FeO and MgSO4. The average density of whole system gradually decreases. Because the mineral partitioned to the core becomes depleted, the moment of inertia factor approaches 0.4 (value taken by a homogeneous body).

3) After the depletion of FeS by oxidation, FeO is oxidized next and magnetite is formed. Because magnetite is partitioned to the core, the core radius increases while the moment of inertia factor decreases. The average density of whole system decreases with decrease in the mantle density because of FeO depletion. Quartz begins to be formed instead of the olivine during decrease in FeO.

4) Once all Fe is partitioned to magnetite, hematite begins to be formed by further oxidation of magnetite. The average density and the moment of inertia factor decrease gradually at this stage with increasing O.

Discussion: The average density and the moment of inertia factor of Io are close to the values obtained at stage 3. Although Io has been suggested to possess lower bulk Fe/Si ratio than the solar ratio on the basis of internal structure model with Fe-FeS core and olivine-dominated mantle (Sohl et al.2002), our results suggest that no fractionation of Fe and Si from the solar abundance is required to account the bulk properties of Io.