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The Distribution of Potassium, Rubidium, and Cesium in the Earth and the Hypothesis of K, Rb, and Cs in the Core

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An elemental mass balance model for the distribution of K, Rb, and Cs in the Earth is constructed using accepted concentrations and K/Rb and Rb/Cs ratios in the continental crust, lithosphere, and depleted mantle, and if required, the core. The geochemical model satisfies the constraint that the whole mantle has a uniform composition, and assumes that the calculated Bulk Earth concentration equals a mean C1 chondrite. The distribution of potassium within the Earth is adopted from a related mass balance model for U, Th, and K that satisfies these same constraints, but in addition, satisfies the global heat flux and rare gas observations. From the homogeneity of potassium isotopes in the solar system it is accepted that volatile loss of potassium, and by analogy, Rb and Cs, did not occur during Earth's formation, and consequently, that the Earth contains the full C1 chondrite abundance of these elements. Potassium is used, together with K/Rb and Rb/Cs ratios, to estimated the distribution of Rb and Cs in the crust, lithosphere, and depleted mantle reservoirs, with any residual K, Rb and Cs necessary to satisfy the C1 chondrite constraint is placed in the core.

The resulting mass balance model requires that the core contains traces of Rb (6.15ppm), Cs (0.55ppm), but a significant amount of K (1,420ppm). The experimental observation that these alkali metals undergo conversion to a metallic state at pressures equivalent to the upper mantle and transition zone provides a mechanism to explain the partial removal of these elements from the primitive mantle to the core. Experiments show potassium will form a stable metal alloy with nickel, once metallization is complete, a result which is in agreement with empirical rules which predict the formation of this K-Ni metal alloy at high pressure. Thus, the downward percolation of a liquid Fe- Ni metal through the "lower" mantle during core formation would strip potassium from the primitive mantle at depths greater than 770 km and sequester it into the core. The same rules predict K, Rb and Cs should also form high pressure metal alloys with Ag and Au, a prediction which has been verified experimentally by the formation of Cs-Ag and K-Au metal alloys in the diamond anvil cell. Because both Ag and Au are depleted in the Earth's mantle and are predicted to be in the core, it is expected that Rb and Cs were also stripped from the primitive mantle by the formation of high pressure metal alloys during core formation.

The predicted Primitive Mantle and Core potassium abundances are tested by comparison to values calculated when a mean C1 chondritic potassium concentration is combined with a recent high pressure and temperature partition coefficient that predicts the partitioning of K between silicate and a Fe-Ni liquid metal. The predicted Primitive Mantle and Core concentrations are 147 ppm and 1,404 ppm, respectively, values which are in excellent agreement with the mass balance model (140ppm and 1,420ppm).

Unlike previous models for the distribution of K, Rb, and Cs in the Earth, which invoke hidden, deep chemical layers within the mantle, the model advocated here satisfies mineral physics, seismic, and isotopic constraints on mantle structure with a geochemically self-consistent model. Therefore, the apparent depletions of K, Rb, and Cs inferred for the Earth are not representative of the Bulk Earth when the effects of high pressure are considered. Sequestering Rb into the core during core formation explains the well known difference between the Rb/Sr ratio of the depleted mantle and the C1 chondrite value and indicates that the Rb-Sr system can provide a constraint on the timescale of core formation, since the Rb/Sr ratio is fractionated by core formation. The recognition that the Earth possesses the full C1 chondrite potassium abundance with most of this sequestered into the core has implications for other so-called depleted elements within the Earth. The Bulk Earth abundance of S may be inferred on the basis of the Earth's Bulk Earth K/Ca ratio, and adopting a chondritic K/Ca ratio will increase the predicted sulfur content of the Bulk Earth. Because it is not possible to distribute the full C1 chondritic S budget within the silicate reservoirs, S must also exist in the core.