Oxygen Isotopes in the Earth and Terrestrial Planets

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Mechanisms that may account for oxygen isotope heterogeneity in meteorites on the microscopic scale do not seem adequate for explaining the similarities and differences in isotopic composition on a planetary scale. In chondrites, most of the isotopic variability can be attributed to photochemical enrichment of the two rare heavy isotopes with respect to the 16O-rich solar composition In the CO, CM, CI, and CR chondrites, an additional low-temperature aqueous alteration leads to mass-dependent further enrichment of the heavy isotopes. If the photochemical origin of the isotopic variation in chondrites is correct, then only a small fraction of meteoritic matter, represented primarily in CAIs, has the solar oxygen isotopic composition, and all other meteoritic components must have undergone photochemical processing. In addition, since the bulk isotopic compositions of the terrestrial planets and of the achondrite parent bodies are similar to those of chondrites, they too must be made of photochemically enriched matter. The photochemical reactions produce chemical disequilibrium in nebular gases, probably leading to a non-equilibrium assemblage of solids, particularly with respect to their oxidation state. These issues emphasize the importance of the measurement of oxygen isotopes in the Genesis solar wind mission.

Within the Earth, oxygen isotope variations are due almost entirely to mass-dependent fractionation effects, giving a line of slope 0.52 on the three-isotope plot. The average crustal composition is 3-4 permil higher in delta 18O than the upper mantle. This difference is too large to be due to igneous fractionation effects alone, and reflects the larger, low-temperature isotope fractionation associated with aqueous weathering reactions at the Earth's surface. Similar effects are not observed in the intraplanetary isotopic variations in the Moon or in the parent bodies of the HED and SNC meteorites.

The bulk oxygen isotopic compositions of Earth and Mars (assumed to be the SNC parent body) cannot be accounted for by any mixture of two components, such as those proposed by Ringwood [1979] and Wanke [1981]. In principle, three-component mixtures of ordinary chondrites, CI, and CV chondrites can match the planetary isotopic compositions, but are inconsistent with chemical compositions. An additional unexplained observation is the exact coincidence in oxygen isotopic composition between Earth and Moon. The correspondence of isotopic composition between the Earth and the enstatite chondrites has been taken by some to have direct genetic significance. In all models using primitive chondrites as building blocks for the terrestrial planets, there is a necessity to remove a major fraction of the moderately volatile elements (alkalies, S, etc.), without altering their isotopic compositions.

Ringwood A. E. (1979) Composition and Origin of the Earth, RSES, Aust. Nat. Univ. (65 pp.).
Wänke H. (1981) Phil. Trans. Roy. Soc. Lond., A303, 287–302