OXYGEN ISOTOPES IN THE SOLAR SYSTEM.

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Mass-independent O isotopic fractionations in CAIs have long been attributed to the mixing of nucleosynthetic components, but no other major elements have shown such nucleosynthetic contribution arguing against this hypothesis. Hence, Clayton (1) proposed that self-shielding of CO in the proto-solar nebula resulted in the preferential production of $^{17-18}$O isotopes, which were then accommodated in solid planetary objects such as Earth, Mars, and meteorite parent bodies. Yurimoto and Kuramoto (2), and Lyons and Young (3) also employed the same process (albeit in different astrophysical settings) to explain the mass-independent O isotope fractionation in CAIs. As a consequence of this process, these authors concluded that the solar O is close to the extreme O isotope composition observed in CAIs (Δ^{17}O ~ -50 permil), and differs from those of planetary bodies such as Earth or Mars (Δ^{17}O ~ 0).

However, since the average values for Δ^{17}O for bulk chondrites and achondrites are close to zero, and their variance becomes smaller with increasing size of a planetary object (Figure 1), Ozima et al (4) argued that all the planetary objects could have been derived by random sampling of a whole planetesimal population which represents the Δ^{17}O value of the protosolar nebula or the Sun. In this preliminary statistical argument, Ozima et al.(4) assumed a specific relation between variance (standard deviation) and the size of planetary object that may not in general be valid. To circumvent this difficulty, here we used a more general statistical approach. The result supports the previous conclusion that terrestrial objects (meteorite parent bodies, Mars, Earth, Moon etc) should have the same O isotope as the Sun. We also discuss its implications on the evolution of the early solar system as well as the origin of the Oxygen isotopes in CAIs.

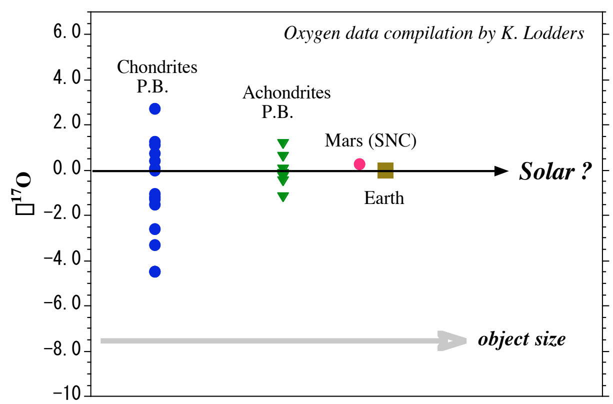

Figure 1. Δ^{17}O for various planetary objects are arranged according to their relative size. Each data point for ch. and ach. is the average of bulk meteorites.

Starting with the Δ^{17}O data of 15 different classes of chondrites (compiled by K.Lodders, written communication), we apply a multistep-multiscale bootstrap method (5) to derive a general relation between the standard deviation (σ) and the size (N) of planetary objects (e.g. chondrite and achondrite parent bodies, Mars, Earth and so on). Here, we assume that planetesimals smaller than a common chondrite parent body progressively accreted to form larger planetary objects such as chondrite and achondrite parent bodies, Mars, and Earth. The σ-N curve is normalized to the standard deviation observed for the 15 chondrite classes (Figure 2). With the use of thus constructed σ-N relation, we estimate the size of achondrite parent body (Nach) relative to chondrite parent body from the standard deviation observed for 9 different classes of achondrites (data compiled by K.Lodders, ibid). The number Nach then corresponds to the number of planetesimals which accreted to have formed an achondrite parent body relative to that of chondrite parent body. This gave (Nach)/(Nch) of 8 ~ 30. If we assume a spherical shape of radius R for a meteorite parent body, the ratio of their radii ($R = (3/4\pi N)^{1/3}$) is 2 ~ 3. The latter ratio appears to be reasonable for the relative size of chondrite and achondrite parent bodies. Also considering that chondrite and achondrite bulk samples have mean values of $\Delta^{17}O$ which are close to zero, we suggest that the planetary objects (chondrite and achondrite parent bodies, Mars, and the Earth) formed from progressive random accretion of planetesimals, and hence should have the same $\Delta^{17}O$ ratio as the solar nebula which represents the average $\Delta^{17}O$ of a whole planetesimal population.

The identical O isotope of various planetary objects with the solar O may imply that the extraordinary CAI O is more likely to be due to local process rather than to nebular-wide process. In this regard, a recent suggestion by Markus (6) that mass-independent fractionation can be attributable to surface reaction of growing CAI grains may deserve closer examination. We also note that the above proposed progressive accretion model is well accommodated within the framework of a current planet formation scenario.

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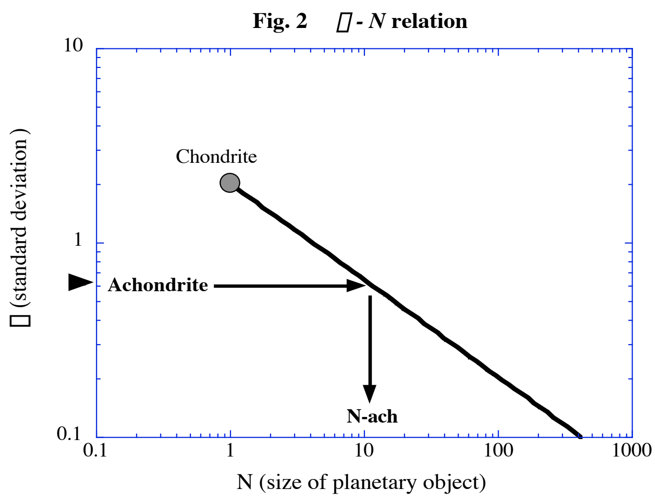

Figure 2. σ -N relation constructed by a multistep-multiscale bootstrap method (5). N is normalized to unity for chondrite.

References: [1] Clayton R. N. (2002) Nature 415, 860-861. [2] Yurimoto, H. and Kuramoto, K. (2004) Science 305, 1763-1766. [3] Lyons, J.R. and Young, E.D. (2005) Nature 435, 317-320. [4] Ozima M., Podosek, F.A., Terada, N. and Seki, H. (2005) MPS 40, A119. [5] Shimodaira, H. (2004) The Annals of Statistics 32, 2616-2641. [6] Marcus R.A. (2004) J. Chemical Physics 121, 8201-8211.