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^{16}O ANOMALIES IN INTERSTELLAR DUST SIZE FRACTIONS.

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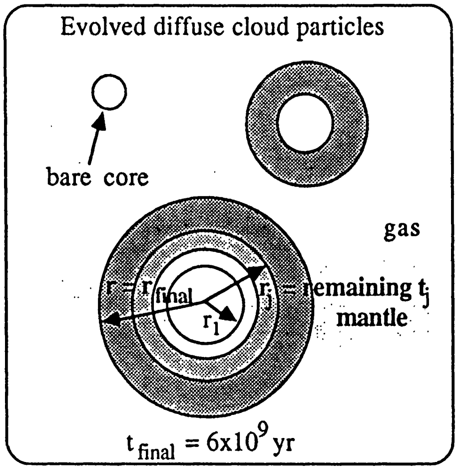

We have computed the dependence of the oxygen isotopic composition of refractory interstellar dust, on average, on the size of the particles. Particles as shown in Fig. 1 acquire an onionskin structure owing to repeated cycles of sputtering of refractory dust by interstellar shock waves followed by reaccretion of refractory gas atoms when diffuse gas and dust transfers to molecular-loud medium, in which all refractory atoms have been accreted by the dust. We follow the evolution of 2 million such particles through 6 Gyr of interstellar history by the techniques introduced by Liffman and Clayton (1). For each of these particles we record the time of accretion of each layer and the eventual mass of that layer (after subsequent sputtering). This enables us to compute an average chemical age $<\tau> = \Sigma m_j \tau_j / \Sigma m_j$, where m_j and τ_j are the masses and chemical age of each accreted shell in the final particle shown above. The results shown in Fig. 2 below clearly demonstrate that, in the molecular clouds, the larger particles are older. This trend has been created by evolution, because all particles have identical age and size profiles at injection.

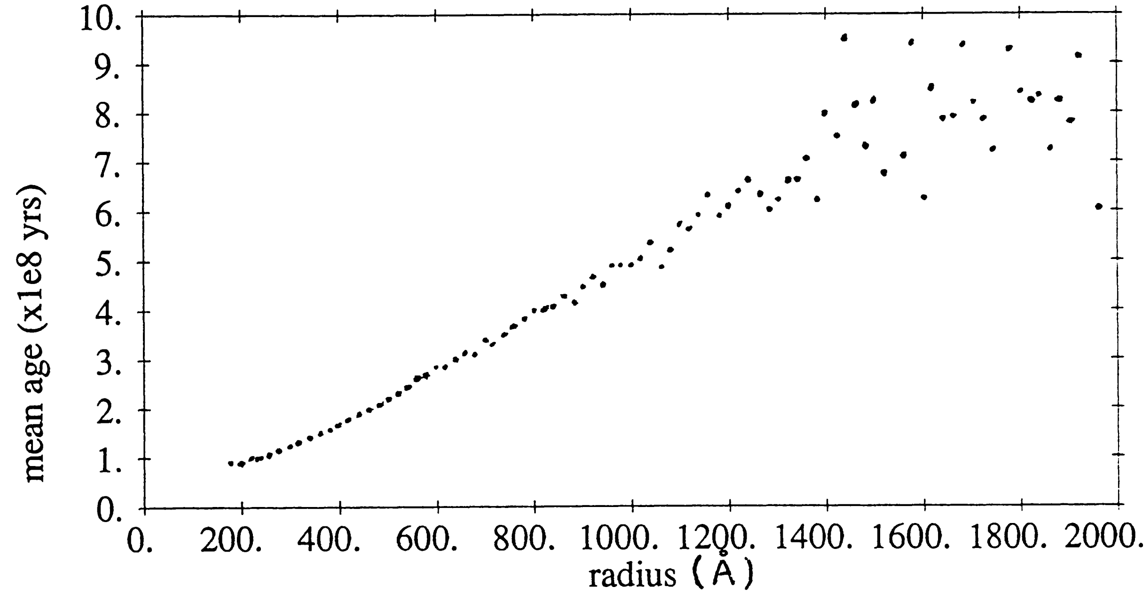

Fig. 2. The average chemical age of all particles having final size in a bin 20Å wide are shown as a function of the mean size (Å) of that bin. The age $<\tau>$ is a composite for each particle of the existence times of its layers, also averaged over all particles in the size bin. Bigger means older! Computed with thermal-sputtering presciption.

The numerical results in Fig. 2 of course depend on the large number of physical assumptions used in the construction of the model. Liffman and Clayton (1) explain these assumptions in detail. We have taken their model based on the a^{-3} injection spectrum between

100Å < a < 1000Å and thermal sputtering in very hot post-shock gases. Numerical experiments with altered assumptions (each calculation requires a few hours on a SUN 3/260) always find a positive correlation of the type shown, though differing in magnitude and detail. Its meaning, rather simply put, is that larger particles have greater probability of containing old interior mantles. The virtue of such explicit calculations is that they demonstrate the size of physical effects to be expected in the evolution of such a particle system.

A specific motive for meteoritic science is an evaluation of the new mechanism of ^{16}O isotopic anomalies recently proposed by Clayton (2). Briefly, interstellar ^{17}O and ^{18}O now increase more rapidly with time in the average bulk interstellar medium than does ^{16}O abundance. This comes about because ^{17,18}O nucleosynthesis yields are proportional to the initial carbon abundance of stars, which is itself increasing with Galactic age. For a Galaxy 6 Gyr old when the Sun formed, the simplest theoretical expectation (2) for the bulk oxygen isotopic composition is $(^{17,18}\mathrm{O}/^{16}\mathrm{O}) = (^{17,18}\mathrm{O}/^{16}\mathrm{O})_\odot t/(6\ \mathrm{Gyr})$. The earlier ISM was deficient in ^{17}O and ^{18}O by equal factors. Stated another suggestive way, the bulk ISM was increasingly ^{16}O-rich at ever earlier times. This means that dust of differing age will show an ^{16}O difference, even if the dust forms with the average composition of the ISM. When we consider the layered particles of Fig. 1 we realize that the older, inner, layers are ^{16}O-rich with respect to the younger outer ones if we assume that when refractory metals are accreted as atoms they combine on the grain surface with accreted oxygen to form refractory oxides. It is not hard to see in this idealized framework that, if the bulk ISM oxygen is defined as normal at the time when the Sun formed, the various particles are ^{16}O-rich in proportion to their average ages $\langle\tau\rangle$. The ordinate of Fig. 2 could therefore be reinterpreted as δ^{16}O. The numeric relation is $\delta^{16}\mathrm{O} = 17 \langle\tau(10^8\mathrm{yr})\rangle$ parts per thousand. All dust is somewhat ^{16}O-rich on this picture. Liffman and Clayton (1) showed (see their Fig. 4) that the mass-average particle in this spectrum is $r \approx 1000$ Å, suggesting that the mean age of all dust is $\langle\bar{\tau}\rangle \cong 5 \times 10^8$ yr, giving $\delta^{16}\mathrm{O} \cong +85$ for mean dust (to be compared with $\delta^{17,18}\mathrm{O} \cong -50$ for the anhydrous minerals of carbonaceous chondrites, where $\delta^{16}\mathrm{O} = -\,\delta^{17,18}\mathrm{O}$). A collection of refractory dust, which should be even older than mean dust, thereby provides a very suitable progenitor for the ^{16}O-rich CAI. This is now seen to be true even without the ^{16}O-rich SUNOCONs that have previously been argued (3) to be the cause of the correlation of ^{16}O with CAI. The interesting question is how CAI, if indeed evaporative residues, managed to avoid the exchange with solar oxygen that appear to be the norm for meteoritic material. An experiment capable of high resolution measurements of solar oxygen isotopes would be very valuable in fixing bulk unfractionated oxygen.

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References: (1) Liffman, K. and Clayton, D. D. 1988, *Proc. Lunar and Planet. Sci. Conf.*, **18**, 637; (2) Clayton, D. D. 1988, *Astrophys. J.*, **334**, 191; (3) Clayton, D. D. 1982, *Q.J.R.A.S.*, **23**, 174.