ISOTOPICALLY ANOMALOUS CARBON IN THE MURCHISON METEORITE AND ITS ASSOCIATION WITH NOBLE GAS COMPONENTS. R.S. Lewis and E. Anders, Enrico Fermi Institute, University of Chicago, Illinois, 60637 U.S.A. and P.K. Swart, M.M. Grady and C.T. Pillinger, Department of Earth Sciences, University of Cambridge, Cambridge CB2 3EQ, U.K.

The Murchison C2 chondrite contains the most complete set of isotopically anomalous noble gas components encountered in primitive meteorites (1): (i) s-Kr and s-Xe, components with isotopic patterns matching those calculated for neutron capture on a slow time scale (=s-process) in red giants; (ii, iii) Ne-E(H) and Ne-E(L), both representing monoisotopic Ne^{22} from decay of (stellar) Na^{22}, but located in phases of high and low release temperature; (iv) CCF (carbonaceous chondrite fission) Xe, attributed either to stellar nucleosynthesis or to processes in the early solar system, such as fission and mass fractionation. All the above components are located in minor, mainly carbonaceous carrier phases constituting less than 0.3% of the meteorite. They are masked by the much larger amounts of normal planetary gases, and must be resolved from them by techniques such as stepped heating or combustion, or separation of carriers by grain size or chemical resistance.

The carbonaceous carriers of exotic noble gas components ought to show quite anomalous $^{12}C/^{13}C$ ratios, given the great variability of this ratio in the galaxy (~4 to >100). Previous studies on C2's (2,3,4) at best showed only modest anomalies, except for a $\delta^{13}C$ of +110°/oo in the 1050° combustion fraction for Murray (5). Even B1B, the CCF-Xe carrier concentrate from Allende only showed a $\delta^{13}C$ of -32°/oo, well within the solar system range (6). We have now measured the carbon isotope composition in 3 separates from Murchison that are ~10^3-fold enriched in exotic noble gases (7). The parent sample, 2C10, had been prepared by repeated treatments with HCℓ, HF, HNO_3, NaOCℓ, and H_2O_2 and was then separated into coarse (3-10μ), medium (1-3μ), and fine (<1μ) fractions by filtration through Nucleopore filters; these fractions constituted 0.121, 0.048 and 0.078% of the original meteorite.

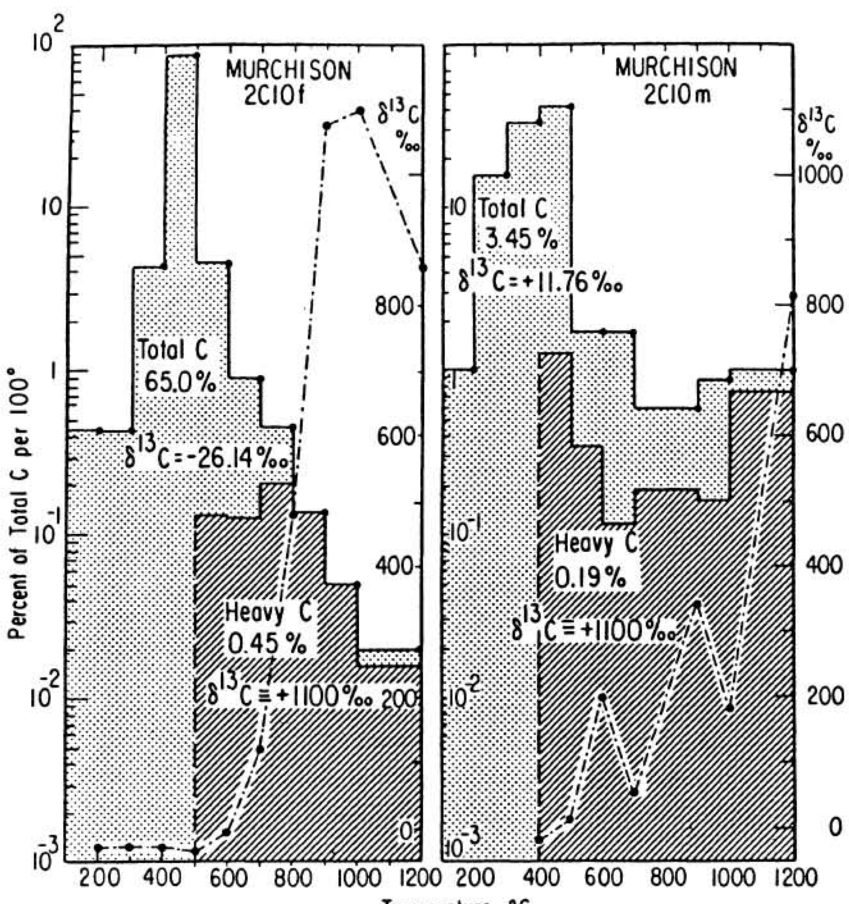
Procedure. Carbon from all samples was released by stepped combustion (8) and was measured as CO_2. Those fractions that were too small for conventional determination were measured by an isotope dilution procedure that is reproducible to ±10°/oo for samples as small as 100ng. The blank, typically 20ng/step, was too small for precise isotopic characterisation, and was therefore taken to have a constant $\delta^{13}C$ of -30°/oo for all temperature steps.

Results. The striking feature of these samples (Fig) is the steep rise of $\delta^{13}C$ above 600°C. For sample 2C10f, the maximum value was +1100°/oo (or +853°/oo before blank correction). The corresponding $^{12}C/^{13}C$ ratio is 42, well below the terrestrial range of ~88-93 and even the mean ratio for interstellar clouds, 60±8. Sample 2C10m has a complex pattern but all the carbon released above 500°C is heavy. Coarse fraction 2C10c was particularly hard to analyse, as the amounts of C approach blank levels, but two different samples showed $\delta^{13}C$ values of +28.6°/oo at 700°C and +18.1°/oo at 1200°C, indicating that 2C10c too, contains some heavy carbon.

The amounts of heavy C can be compared on a pro forma basis, by assuming that each sample is a binary mixture of heavy C of $\delta^{13}C \equiv +1100$°/oo and light C equal to the lightest $\delta^{13}C$ seen in that sample (i.e. -38°/oo to -20°/oo). The corresponding release patterns are shown by diagonal shading in the figures. The release pattern from 2C10m is extremely broad, suggesting that more than one type of heavy C is present. The concentration of heavy C is highest in 2C10f -- some 10^3 times higher than in the bulk meteorite (4500ppm vs ≳4.1ppm).

Discussion. S-process gases and Ne-E(L) both seem to be linked to heavy carbon. The outgassing temperatures for Ne-E(L) and s-process Kr, Xe are very far apart: ~600°C and ~1400°C respectively (9,10). Though outgassing and combustion are quite different processes, both depend on grain size and structural stability. A phase labile at a given T during pyrolysis must be at least as labile during combustion at the same T. For this reason, we tentatively assign the 900-1200°C carbon to s-Kr, Xe and the 500-600°C carbon to Ne-E(L). In support of this assignment we note that 2C10c, the sample with the highest ratio Ne-E(L)/s-Xe (7) releases a disproportionately large part of its heavy C at 500-700°C rather than 1200°C. We stress, however, that the δ^{13}C for low-T heavy carbon is impossible to assess (minimum value is +200°/oo from 2C10m) because it is contaminated with isotopically light polymer carbon. Moreover, it is possible that more than two types of heavy C are present. The high-T type may represent graphite grains condensed at high T, whereas the low-T type(s) may be fine-grained, amorphous carbon, formed at lower temperatures.

The isotopic anomalies for heavy C in Murchison are large and must reflect nucleosynthetic rather than mass fractionation processes. The carbon data alone do not point to a specific stellar locale, as carbon of low ^{12}C/^{13}C ratio can be made in stars of a range of masses and evolutionary stages. However, the association of high-T heavy C with s-process Kr, Xe points to red giants or still later stellar types (10,11). The origin of low-T heavy C is less constrained, as the Na^{22} parent of its noble gas marker, Ne-E(L), can be made either by He burning in red giants, or by a variety of nuclear processes in stars of later types. This work is supported by NASA grant NGL 14-001-010 and by the Science and Engineering Research Council.



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