INTERSTELLAR GRAPHITE AND OTHER CARBONACEOUS GRAINS FROM THE MURCHISON METEORITE: STRUCTURE, COMPOSITION AND ISOTOPES OF C, N, AND Ne; *E. Zinner and B. Wopenka*, McDonnell Center for the Space Sciences, Washington University, St. Louis, MO 63130-4899, and *S. Amari and E. Anders*, Enrico Fermi Institute, University of Chicago, Chicago, IL 60637-1433.

CI and CM meteorites contain an exotic noble gas component, Ne-E(L), which consists of almost pure ^{22}Ne and is released upon heating around 600°C [1,2]. We succeeded in enriching its carrier, Cα, in the Murchison carbonaceous chondrite by a factor of 1.5×10^5 over the bulk meteorite by a series of chemical and density separation steps [3,4]. These included treatment with HCl-HF, $Cr_2O_7^=$ in 1M H_2SO_4, and removal of colloidal material, followed by cautious oxidation with NaOCl and alkaline H_2O_2. Of four density separates, Murchison LFC (1.75-2.2 g/cm^3, 1 ppm of the meteorite) has the highest Ne-E(L) content ($^{22}Ne_E = 4240 \times 10^{-8}$ cm^3/g) and consists of abundant aggregates of ~ 0.1 μm spherules and fewer dense particles. Ion probe analysis [3,4] showed that the aggregates have isotopically normal C and moderately heavy N (average $\delta^{15}N \approx +300$ ‰), whereas the dense grains have extremely anomalous C (both light and heavy). Ultrasonication and size-separation (>1 μm) of LFC removed most aggregates, resulting in LFCl (~0.3 ppm), which is even more enriched in Ne-E(L) ($^{22}N_E = 14{,}000 \times 10^{-8}$ cm^3/g), indicating that this gas component is carried by the dense grains or of a subclass of them.

Morphology and Isotopic Composition. In order to better characterize the Cα we selected 90 individual grains, deposited on gold foil from a suspension of LFCl, and studied them by SEM (EDX) and ion microprobe analysis for their morphology, chemistry and C and N isotopic compositions. Raman spectroscopic information was obtained on 13 grains. All grains consist predominantly of carbon and comprise a) round forms, b) plates of different sizes and shapes including euhedral crystals with hexagonal outlines, c) irregular blocky shapes, often with smaller attached debris and d) dense clusters of spherules mostly larger than those of the aggregates in LFC. The isotopic compositions strongly depend on morphology. Only the round grains, plotted in Fig. 1, have highly anomalous carbon, $^{12}C/^{13}C$ ranging from 0.08 to 50 × solar. Grains of all other morphologies have essentially normal C ($\delta^{13}C$ from − 70 ‰ to + 8 ‰) and a limited range in their N isotopic composition ($\delta^{15}N$ from −54 ‰ to +250 ‰). They are too numerous to show in Fig. 1, but they all fall inside the shaded rectangle in the inset of Fig. 1 except for one blocky grain with slightly heavier N.

Crystalline State. The round grains vary in size from 1.5 μm to 6 μm. Many are well-formed spheres but some are more irregular, resembling potatoes. Some are very smooth (mostly the smaller spheres) but many have complicated surfaces consisting of densely packed subunits, in some cases displaying a shell structure. Concentrations of other elements vary considerably. H^-/C^- and CN^-/C^- ratios measured in the ion probe vary by factors of 30 and 200, respectively, and are correlated with one another. Two grains with large H^-/C^- and CN^-/C^- ratios (both also with large ^{13}C excesses) were unstable in the laser beam of the Raman microprobe and melted, indicating an organic composition. The other grains probed by laser Raman spectroscopy were selected to have much lower H^-/C^- and CN^-/C^- ratios. They give spectra characteristic of graphite with varying degrees of disorder (Fig. 2).

Spectrum 2a, of a euhedral hexagonal plate, indicates well crystallized graphite by the narrow first-order band at 1575 cm^{-1}, the almost total absence of a band at ~ 1350 cm^{-1}, the asymmetric shape of the second-order band at ~ 2700 cm^{-1}, and the presence of faint second-order features at 2450 and 3220 cm^{-1}. With increasing disorder the 1575 cm^{-1} band becomes wider, the 1350 cm^{-1} band increases in intensity and the 2700 cm^{-1} band becomes more symmetric (Fig. 2b). The overall background, falling off with increasing relative wavenumber, suggests the presence of some organic molecules as a source of fluorescence. Finally, the first-order spectrum shown in Fig. 2c indicates a large degree of disorder with crystallite sizes of less than 100 Å and higher concentration of organic molecules (still, this grain was stable in the laser beam). The latter, however, is a rare case as the spectra of the other 8 round grains fall between those of Fig. 2a and Fig. 2b. Thus, round grains range from

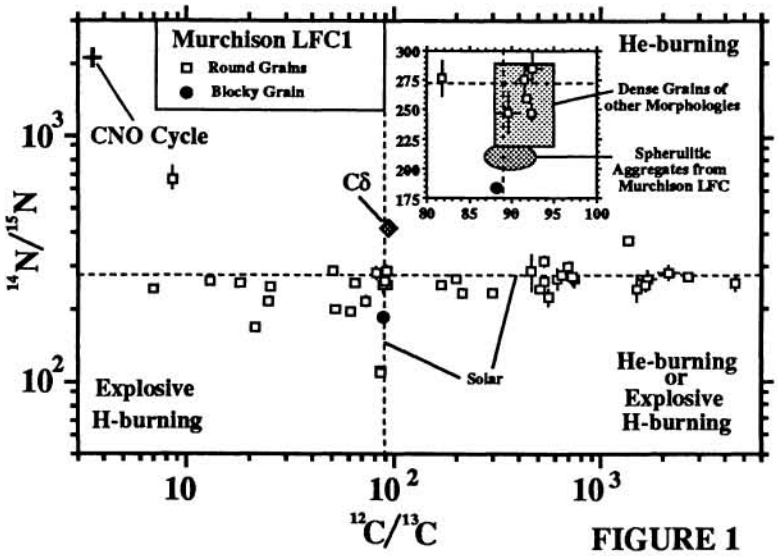
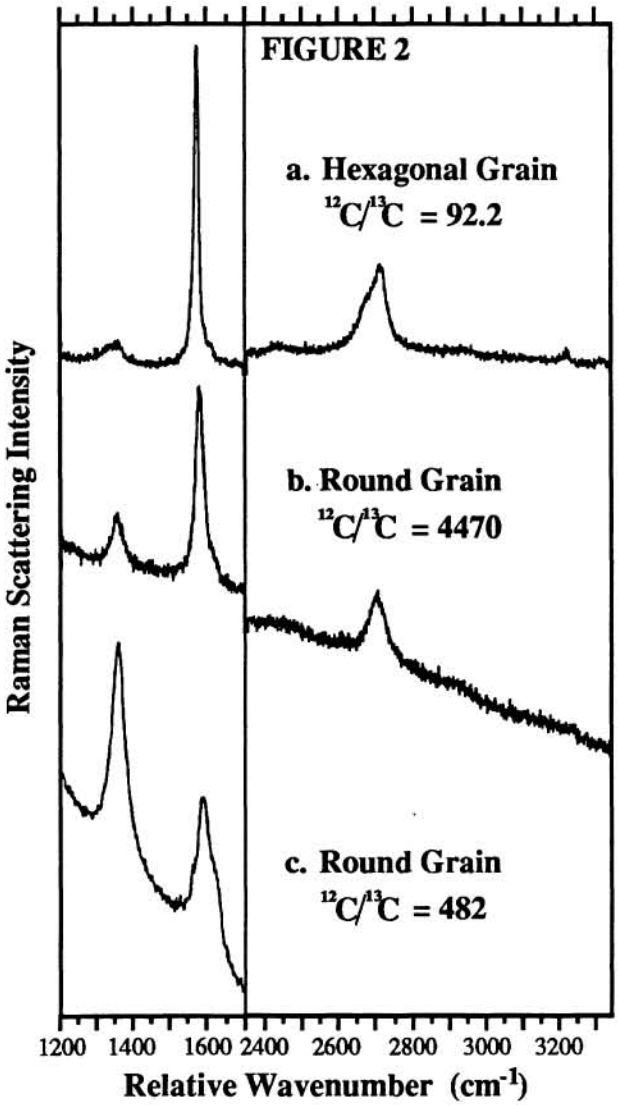


FIGURE 1



almost pure, well-crystallized graphite to some kind of still unknown organic composition.

Chemical Composition. Because of matrix effects, low energy ion ratios are not very reliable measures of elemental concentrations. Still, if we compare the H^-/C^- and CN^-/C^- ratios obtained with those from diamond-like hydrocarbon and our N-isotopic standards (thymine and 1-hydroxybenzotriazole hydrate) the maximum values for these ratios would correspond to atomic concentrations of 22%H and 0.6-2.7% N. Interestingly, there is a rough general correlation between the C isotopic and chemical composition of the round grains in that isotopically heavy grains have, on average, higher H and N contents than isotopically light grains. Since the round grains are most likely the Ne-E(L) carriers, the question arises whether all of them contain this gas component or only a subclass with specific chemical and isotopic characteristics.

Novae have previously been proposed as stellar sources for Ne-E [5]. A few grains indeed have the ^{15}N excesses predicted for this origin, but the modest ^{15}N enrichment is surprising, as is the limited range of $^{14}N/^{15}N$, in view of the large variations in $^{12}C/^{13}C$. While the measurements of grains with low N (the lower limits of CN^-/C^- approach blank levels seen in the terrestrial NBS-21 standard) are likely to be dominated by terrestrial contamination, this is not expected to be the case for most of the round grains. The spherical shapes, resembling soot in flyash, are likely to result from condensation in stellar atmospheres [6]. However, it is an open question whether H and N are primary constituents or were later added by interstellar processes.

References: [1] M.H.A. Jungck and P. Eberhardt (1979) Meteoritics **14**, 439; [2] E. Anders (1988) In *Meteorites and the Early Solar System*, (J. F. Kerridge, ed.), Chapter 13.1, University of Arizona Press, 927-955. [3] S. Amari *et al.* (1989) Meteoritics **24**, ; [4] S. Amari *et al.* (1990) Nature, submitted; [5] D.D. Clayton (1975) Nature **257**, 36. [6] H. Kroto (1988) Science **242**, 1139.