HYDROGEN ISOTOPIC VARIATIONS IN INTERPLANETARY DUST PARTICLES; K. D. McKeegan, P. Swan, R. M. Walker, B. Wopenka, and E. Zinner, McDonnell Center for the Space Sciences, Washington University, St. Louis, MO, 63130, USA.

Previous ion probe investigations have shown that a substantial fraction of chondritic interplanetary dust particles (IDPs) exhibit large deuterium enrichments relative to terrestrial D/H values [1]. The D excesses in 5 of these partices are spatially correlated with the relative abundance of carbonaceous material, indicating a carbonaceous carrier of the D/H anomaly. As is the case for organic matter in primitive meteorites [2,3], the size of the D/H anomalies provides indirect evidence for the preservation of organic molecules formed by ion-molecule reactions in cold molecular clouds.

We give here a summary of the results of ion probe D/H measurements in 31 individual IDPs of nearly chondritic composition and 2 Fe-Ni-S (FSN) IDPs [4]. Complementary mid-infrared absorption spectroscopy has been performed on 20 of these particles, significantly expanding the database for investigating possible correlations of H isotopic composition with IR class [5]. Raman microprobe measurements, which can yield information on the chemical state of carbonaceous material, have been made on 20 particles analyzed in the ion probe; the results are discussed in a companion abstract [6].

The ion microprobe D/H measurements are made by techniques similar to those described in [1]: the sample is pressed into a clean Au foil and negative ions, sputtered by a focussed (~ 5 μm diameter) Cs^+ beam, are analyzed at low mass resolving power. Particles often break up upon being crushed into the Au, and measurements are typically made on several fragments from each particle. An actinolite standard is used to correct for instrumental mass fractionation effects; the measurement precision is typically ~ 50 ‰, although for very small samples (≤ 50 pg), or particles with very large δD values, it can be 100 - 200 ‰.

Of the 31 chondritic particles, 13 have fragments with δD > 100 ‰ (SMOW scale) with 3 of these (Mosquito, Calrissian, and Butterfly) exhibiting values > 2,000 ‰ (Table 1). One of the FSN particles has a δD up to 173 ‰, the other has a terrestrial D/H ratio. The total range in δD observed is from -386 to 2705 ‰ and all particles with D excesses have H isotopic compositions that are heterogeneous on a size scale of microns, reflecting the unequilibrated nature of the particles. The particles with D excesses - except Butterfly (discussed below) - show a correlation of δD with carbonaceous material as measured by the ion signals of H^- and C^- relative to O^- or Si^-. In the following we summarize the ion probe observations of IDPs from different IR classes.

PYROXENES: Four of 7 particles that have pyroxene as the dominant silicate phase (6 were measured by IR, Mosquito by electron probe) exhibit large D excesses of up to 494 ‰ (Cedarcreek), 1094 ‰ (Spray), and 2534 ‰ (Mosquito). Butterfly (δD values up to 2705 ‰) is classified here as a pyroxene, but the IR spectrum also has some features that are characteristic of layer-lattice silicates. Pyroxene IDPs are generally anhydrous and are characterized by fluffy morphologies and high porosities [7]. The H^- and C^- ion signals for these 7 particles are strongly correlated with each other and are not associated with silicate grains (with the possible exception of Butterfly).

LAYER-LATTICE SILICATES: Five of 12 LLS particles (9 identified by IR, 3 by TEM [8]) have fragments with δD > 100 ‰. In general, these particles have lower abundances of carbonaceous material than the pyroxene class particles and because there is a significant water component, the C and H are not as closely correlated. Nevertheless, individual particle fragments do show that the high δD phase is associated with carbonaceous material, although for the whole class, the correlation is tentative due to different OH concentrations between different particles. All the evidence is consistent with the hydrated component being isotopically close to SMOW or, perhaps, somewhat depleted in D.

OLIVINES: Of 5 IDPs identified as IR olivines, none have any D excess. The C^-/O^- ratios are fairly constant and are comparable to the lowest values observed for the pyroxene and LLS particles.

Although one must be wary of the statistics of small numbers, the H isotopic data are consistent with a scenario proposed by Bradley and Brownlee on the basis of petrographic data for thin-sectioned IDPs whereby the pyroxene and layer-lattice silicate type particles are derived from a common parent [9]. The light element abundances and H isotopic data suggest that the olivine type particles may have a different source than the pyroxene or layer-lattice silicate IDPs.

In the IDP Butterfly, the carrier phase of the D excess is heterogenously distributed within a host silicate matrix on a size scale smaller than the minimum Cs^+ spot size obtainable. Because this phase is such a minor component, the dilution of the D excess is large and the C^-/O^- and H^-/O^- ratios do not vary much and hence do not show a good correlation with δD. In order to study the distribution of the excess D in this IDP we utilized the ion imaging capabilities of the CAMECA IMS-3f which allows a spatial resolution of about 1 μm. Fig. 1 shows the ion images of a fragment of Butterfly for H^-, D^-, $^{12}C^-$, and $^{16}O^-$. The average δD measured in the probe mode for this fragment is ~ 1400 ‰. The O^- image delineates the size of the grain which is predominatly silicate material. Note that the D is not distributed uniformly with the O or the H, but is concentrated in a "hot spot" which has a size comparable to the resolution of the IMS-3f. By digitizing these images and integrating over ~ 1 μm^2 areas, it is possible to estimate the relative concentration factor for the D in the hot spot. A lower limit estimate of the δD value in the D-rich spot is ~ 9,000 ‰. This is the highest D/H value observed in solar system material, and approaches values measured by radio astronomers [10]. Because of the extreme isotopic composition and the small size scale of the hot spot it is a promising candidate for preserved interstellar material in IDPs. Results of experiments to characterize the "hot spot" will be discussed at the meeting.

REFERENCES: [1] McKeegan *et al.* (1985), *GCA* **49**, 1971. [2] Kolodny *et al.* (1980), *EPSL* **46**, 149. [3] Yang and Epstein (1983), *GCA* **47**, 2199. [4] Fraundorf *et al.* (1982), *JGR* **87**, A403. [5] Sandford and Walker (1985), *Ap. J.* **291**, 838. [6] Wopenka, this volume. [7] Bradley and Brownlee (1986), *Science* **231**, 1542. [8] Bradley (1986), personal communication. [9] Bradley and Brownlee (1986), 49th Meteoritical Soc. Abstracts. [10] Zinner (1987) in *Meteorites and the Early Solar System.*

Table 1. D/H, IR, and Raman data for chondritic IDPs.

Particle name	IR class†	Raman (ref [6])	δD range (‰, SMOW)
Summersville	LLS	Y	-1 → 76
Verona A	LLS	Y	-237 → -74
Jefferson City	LLS	Y	-197 → 3
Skywalker	LLS	Y	51 → 696
Lea	LLS	Y	-386 → 159
Calrissian	LLS	Y	373 → 2191
Speckles	LLS	N	-266 → 61
Yoda	LLS	N	-259 → 68
Xavier	LLS	N	-274 → 151
Chicago-2	(LLS)	N	-34 → 111
Chicago-3	(LLS)	N	-81 → -64
Chicago-5	(LLS)	N	4 → 33
Spray	Pyx	Y	370 → 1094
The Clown	Pyx	Y	-145 → 64
Pattonsburg	Pyx	Y	-182 → -132
Cedarcreek	Pyx	N	69 → 494
Carrolton	Pyx	Y	-55 → -8
Butterfly	Pyx+	Y	-322 → 2705+
Mosquito	(Pyx)	Y	125 → 2534
Essex	Ol	Y	-270 → -193
Attila	Ol	Y	-193 → 12
Ptaar	Ol	Y	-169 → 64
Viburnum	Ol	Y	-218 → -30
Cannonball	Ol	Y	-134 → -59
Tyson	n.a.	Y	-299 → -236
Solo	n.a.	N	270 → 742
Rocheport	n.a.	N	474 → 643
Pb-1	n.a.	N	-5 → 104
Pb-2	n.a.	N	-86 → -69
SP-56	n.a.	N	-340 → 319
SP-88α	n.a.	N	713 → 1345

† Some IR data are from [5]. Parentheses indicate classification by means other than IR spectroscopy.

Figure 1. Ion images of H^-, D^-, $^{12}C^-$, and $^{16}O^-$ for a fragment of Butterfly. The D-rich "hot spot" has an estimated δD ≥ 9,000 ‰.