

DISTRIBUTION AND ABUNDANCE OF Q-Xe CARRIERS IN ACFER 094 MATRIX. S. A. Crowther, H. Busemann and J. D. Gilmour, School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Manchester, M13 9PL, UK (sarah.crowther@manchester.ac.uk)

Introduction: Analysis of individual interplanetary dust particles (IDPs) and other grains of cosmological interest is challenging due to their small size. These grains can only be individually analysed using the most sensitive experimental techniques available. However such analyses can provide precious information about their history, which could be lost when grains are analysed in bulk.

Concentrations of ^{132}Xe are estimated to be only a few thousand atoms in a 10 ng IDP [1], below the detection limit for most conventional, low-blank noble gas mass spectrometers. However analysis of individual grains is feasible using RELAX (Refrigerator Enhanced Laser Analyser for Xenon), an ultrasensitive mass spectrometer for xenon analysis [2, 3]. The spectrometer blank is currently estimated to be only ~500 atoms ^{132}Xe , a factor of 10 lower than during previous attempts to analyse individual IDPs [4]. Similarly the estimated detection limit of ~1000 atoms ^{132}Xe (based on three times the standard deviation of the blank) is about five times better than previous attempts. In light of this improvement in the blank and detection limit, we are re-establishing single grain xenon analysis. Preliminary IDPs analyses are presented in an accompanying abstract [5].

The primitive carbonaceous chondrite Acfer 094 (ungrouped C2) provides an ideal analogue to further develop this technique. The bulk concentration of ^{132}Xe is 1.1×10^{-8} cc STP g^{-1} [6], comparable to that which might be expected in individual IDPs [1].

Experimental: 28 individual samples of Acfer 094 matrix, ranging between about 10 and 40 μm in diameter, have been analysed for xenon using the RELAX mass spectrometer [2, 3]. Prior to being loaded into the RELAX mass spectrometer samples were placed on to a gold foil mount, and 20 of the 28 samples had been analysed by nanoSIMS to identify any presolar grains: presolar silicates were found in 5 samples, oxides in 4 grains and SiC in 6 samples, including one sample with both silicate and oxide grains and another containing both silicate and SiC grains [7, 8].

Samples were heated for 1 minute with the focused output of a continuous wave Nd:YAG laser. The laser power was gradually increased over this minute, to avoid the samples “jumping” away when first hit by a high intensity laser beam. All except for one sample were observed to glow or flash under the laser beam, confirming that they were being heated by the laser.

Sample analyses were interspersed between numerous measurements of air calibrations and blanks.

Results: The concentrations of ^{132}Xe for all samples, corrected using the mean and standard deviation of the blank, are shown in Fig. 1. As the samples have been pressed into gold foil, they cannot be assumed to be spherical, therefore the concentrations are given per unit of the observed radius cubed (μm^{-3}); this quantity differs from the concentration per unit volume by some (unknown) factor which, it is assumed, is not a major source of the apparent (factor >10) variation in concentration (though it may introduce a systematic offset). The mean ^{132}Xe concentration across all 28 samples analysed is 2.0 ± 0.5 atoms $^{132}\text{Xe} \mu\text{m}^{-3}$. Assuming a bulk density of 3 g cm^{-3} , this corresponds to a concentration of ^{132}Xe of 2×10^{-8} cc STP g^{-1} . This probably under-estimates the true concentration of ^{132}Xe in the samples analysed here because we have assumed a cubic volume, but in reality the samples would have been flattened when pressed into the gold foil. Thus our data suggest a higher concentration of Xe than observed in the bulk meteorite. Those analyses which appear to contain a negative concentration of ^{132}Xe contained less gas in total (blank + any gas released from the sample) than the mean of 55 blank analyses, and are consistent with statistical variation in the blank. There is no significant dependence of concentration on the presence or type of presolar material

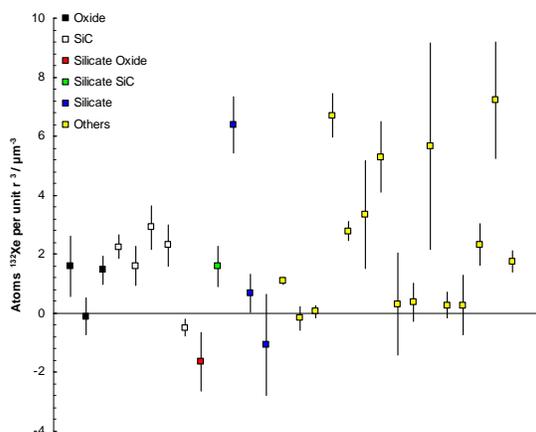


Fig. 1. Concentration of ^{132}Xe in 28 individual samples of Acfer 094 matrix, ranging between about 10 and 40 μm in diameter. Samples are grouped according to the types of any presolar grains detected in them, by nanoSIMS measurements [7, 8]. As the samples can not be assumed to be spherical, the concentration of gas is calculated per unit of the radius cubed (μm^{-3}).

(SiC-, silicate-bearing, etc) in the samples analysed.

Discussion: This distribution of ^{132}Xe concentrations implies that the number of discrete xenon carriers is of the same order of magnitude as the number of samples analysed. If xenon was hosted by a large number of carriers (relative to the number of samples analysed) we would expect to see them more uniformly distributed throughout the samples, and gas concentrations to cluster close to the mean value, approximating a Normal distribution; were gas hosted by a very small number of carriers we would expect a bimodal distribution, with only a very small number of samples containing all the gas and the remainder containing no gas.

A probability density function for the concentration of ^{132}Xe has been calculated (Fig. 2) by assigning a unit area Normal distribution to each datum, with a width corresponding to the error in the concentration, and summing these together. One of the samples was anomalously large (over 40 μm observed diameter), and has been excluded from this process.

To estimate the distribution of carriers of Q-Xe, we compare the distribution derived from our data with models where the total number of carriers in our entire sample suite (N) is 10, 100 and 1000 (Fig. 3). It is assumed that the total gas observed is equally distributed among the N carriers. The probability distribution of the number of carriers in each one of our samples is then estimated using a Poisson distribution, where the mean number of carriers in each individual sample is proportional to the fraction of the total volume (of all the samples) represented by that sample's volume. From this a probability distribution for the Xe concentrations in each sample is derived. These are summed to produce a model distribution that can be compared with that observed (Fig. 2). The comparison suggests the total number of gas carriers in all the samples is of order 100 (Fig. 3) – this produces a profile similar to the experimental distribution, with a main peak corresponding to around 2 atoms of ^{132}Xe per cubic μm , and a subsidiary peak at slightly higher concentrations. A total of ~ 51000 atoms ^{132}Xe were measured in these samples, therefore 100 gas carriers correspond to each carrier containing ~ 510 atoms ^{132}Xe .

We estimate that the typical grain size in the samples analysed in this work is ~ 500 nm. If our assumption that the grains are roughly spherical is valid, the total number of grains in these samples is therefore $\sim 10^6$. If our samples were are less deep by a factor of 10 due to the compression experienced as they were mounted, the total number of grains would be $\sim 10^5$. Although the model derived here for the distribution of Q-Xe carriers is greatly simplified, it suggests that only

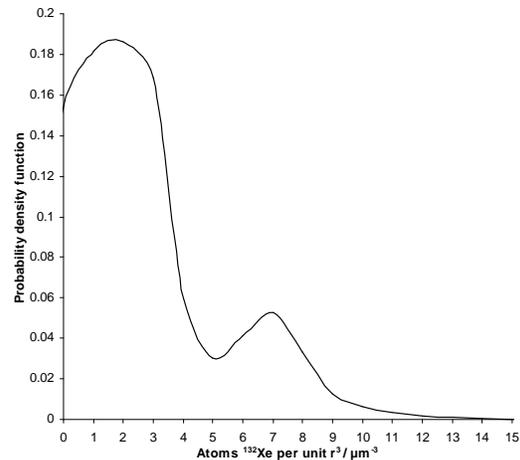


Fig. 2. Probability density function for the concentration of ^{132}Xe for 27 of the Acfer 094 samples analysed. The individual data points in Fig. 1. are assigned a unit area Normal distribution, with a width corresponding to the error in the concentration determination, and summed together.

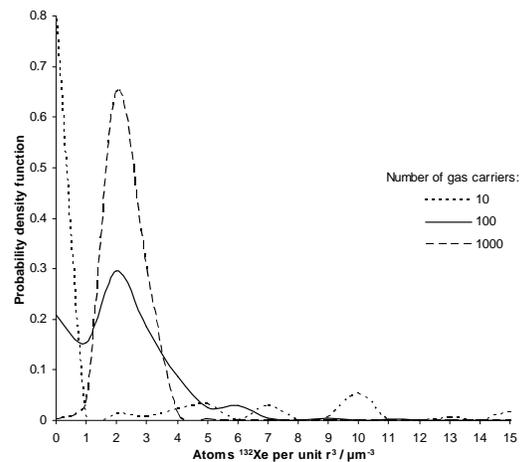


Fig. 3. Modeled concentration distributions based on presence of $N=10$, 100 and 1000 gas carriers in our total samples suite. This model suggests the total number of gas carriers in all the samples is around 100.

on the order of 1 in $(1-10) \times 10^3$ of these grains is a carrier of Q-Xe.

References: [1] Crowther, S. A. et al. (2006), *LPSC XXXVII*, Abstract # 1942. [2] Crowther, S. A. et al. (2008) *JAAS*, 23, 938-947. [3] Gilmour, J. D. et al. (1994) *Rev. Sci. Instrum.*, 65, 617-625. [4] Kehm, K. et al. (2009) *Meteoritics & Planet. Sci.*, 44, 249-259. [5] Busemann, H. (2010), *LPSC XLI*, Accompanying Abstract. [6] Scherer, P. and Schultz, L. (2000) *Meteoritics & Planet. Sci.*, 35, 145-153. [7] Davidson, J. et al. (2009), *LPSC XL*, Abstract # 1853. [8] Davidson, J. (2009) PhD Thesis, The Open University.