**NOBLE GAS MEASUREMENTS OF THE GRANT IIIAB IRON METEORITE.**

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**Introduction:** In contrast to stony meteorites, which have exposure ages usually not higher than a few tens of million years, most iron meteorites exhibit cosmic-ray exposures of hundreds of million years. Consequently, iron meteorites have collected information about the solar system, encoded in *cosmogenic nuclides*, for much longer than stony meteorites. Iron meteorites are therefore indispensable for long-term studies of solar system dynamics. For example, the still open question of whether there has been any long-term change in the galactic cosmic-ray (GCR) intensity is only accessible using iron meteorites. The study of long-term changes in the GCR is important for several reasons. First, unobserved variations in the GCR intensity compromise exposure age studies of the dynamics within the asteroid belt. Second, a possible variability of the GCR might give some information about the number of galactic spiral arms and, third, it has been argued that changes in the GCR intensity could affect the Earth's climate [1]. However, for such studies a consistent database of cosmogenic nuclides in iron meteorites together with physical model calculations to understand their production mechanisms are mandatory.

In the noble gas laboratory of the University of Bern, we are now able to routinely measure the helium, neon, and argon isotopic concentrations in iron meteorites. In order to study how to handle iron meteorites, i.e. extract and clean the noble gases and choose appropriate sample weights, a variety of experiments were performed. The first experiment was a stepwise heating procedure using Grant (IIIAB) samples. There we determined what temperature is needed to degas iron meteorite samples. In the second experiment, the spatial distribution of noble gases in Grant has been tested in order to choose representative sample weights for further analyses. After having successfully demonstrated that we are able to accurately and precisely measure noble gases in iron meteorites, the next step was the recalibration of the preatmospheric center of Grant. This is of particular importance because several (empirical and semiempirical) models developed to calculate cosmogenic production rates in iron meteoroids, e.g., the Signer-Nier model [2] and the Voshage model [3], are based on Grant data.

**Methods:** Two different experimental set-ups are used to degas and analyze the samples. One is a conductive heating system connected to a MAP 215-50 mass spectrometer. The other is a RF-heating system connected to two self-made sector field mass spectrometers, one to measure helium and neon the other to measure argon. In order to avoid corrosion of the molybdenum (Mo) crucible during the melting of the iron samples, a boron nitride (BN) liner is placed within the Mo crucible. The helium blank contribution to a typical sample is less than 0.1% for both systems. For neon, the blank usually is less than 2% (< 0.1% for MAP) and for argon the blank contributes less than 0.5% (< 0.1% for MAP).

**Experiments:** The stepwise heating experiments demonstrated that for the conductive-furnace system a temperature of ~1800°C is required to fully (> 98%) degas the samples. A second heating step at 1850°C ensures complete degassing. The relatively high temperature needed might be because the temperature is measured at the bottom of the Mo crucible, not in the BN-liner. The stepwise heating experiments demonstrated that the isotopic ratios of helium, neon, and argon become cosmogenic as soon as the released gas amount is measurable. Other noble gas components, such as trapped gases, are (at least in Grant samples) negligible compared to the cosmogenic component.

In the second experiment we studied whether trace elements, e.g. sulfur and phosphorous, influence cosmogenic nuclide production. To do so, we analyzed Grant samples with masses between 25–150 mg in order to investigate whether the measured gas concentrations in small samples show more scatter than in larger samples. Surprisingly, the gas amounts show no increased scatter for smaller samples. This means either that micro minerals have no influence on noble gas production or that they are homogeneously distributed in the sampled weight range. For further analyses, sample weights of 50 – 100 mg were used.

**Preatmospheric center of Grant:** To validate model calculations for cosmogenic production rates in iron meteorites, the iron meteorites Grant and Carbo (IID), which have been cut almost through their preatmospheric centers, can be used. From the center slice of Grant five bars have previously been extracted: Bar B, Bar F, Bar J, Bar N, and Bar R. Using samples from all five bars two independent depth profiles have been measured by us so far: One along Bar B and one perpendicular to Bar B (Fig. 1).

To determine shielding depths in iron meteorites, the isotopic ratios $^{4}He/^{21}Ne$ and $^{36}Ar/^{38}Ar$ can be used [4]. While $^{36}Ar/^{38}Ar$ is lowest at the preatmospheric center, $^{4}He/^{21}Ne$ reaches a maximum value [4].

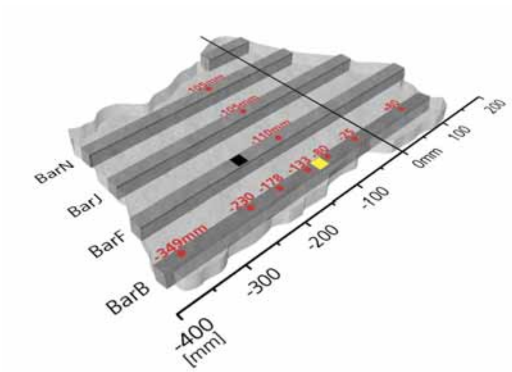


**Figure 1:** Two profiles have been measured (red symbols). Black square: Center determined by Signer & Nier [2]. Yellow square: Center determined by this work.

The profile perpendicular to Bar B (From Bar N to Bar B) shows decreasing $^{36}Ar/^{38}Ar$ ratios from Bar N towards Bar B whereas the $^{4}He/^{21}Ne$ ratios increase from Bar N to Bar B (Fig. 2, upper panels). From this data, we can conclude that the preatmospheric center location was close to or even slightly below Bar B. The profile measured on Bar B shows minimum $^{36}Ar/^{38}Ar$ ratios about 100 mm left from the reference line. This finding is in agreement with $^{4}He/^{21}Ne$, which shows highest ratios at nearly the same location (Fig. 2, lower panels). Therefore, we can conclude that the preatmospheric center of Grant was close to Bar B about 100 mm left from the reference line.

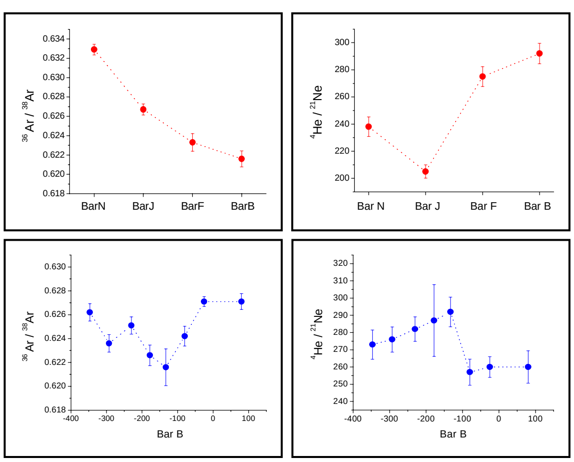


**Figure 2:** $^{36}Ar/^{38}Ar$ and $^{4}He/^{21}Ne$ ratios for the two profiles (upper panels: Bar N to Bar B, lower panels: along Bar B)

The new center location differs from the previously assumed location [2, 3] (Fig. 1). Consequently, the empirical and semiempirical models by Signer & Nier [2] and Voshage [3] are based on an incorrect center location and can therefore not be correct. A new model able to calculate the production rates for cosmogenic nuclides in iron meteorites is urgently needed.

To begin the establishment of a precise and consistent database for cosmogenic nuclides in iron meteorites we have measured helium, neon, and argon in Arispe (IC), Cape of Good Hope (IVB), Navajo (IIB), and Negrillos (IIA). Beside our general interest in iron meteorites, those data are also needed for correcting Hf-W data for cosmogenic contributions (Markowski et al., this conference). The results for cosmogenic $^{3}He$ are given in Table 1. Compared to earlier measurements [5] our results for Negrillos, Navajo and Cape of Good Hope are about 40%, 20% and 10% higher, respectively. For Arispe the new value is within the range of the six values published so far [5]. However, the large $^{4}He/^{21}Ne$ ratios between 300 and 400, not shown, indicate that the four meteorites were large and that the scatter of the data can therefore be explained by different shielding conditions of the samples analyzed. Note that the $^{3}He$ concentrations in Grant determined by us agree very well with earlier measurements.

| $^{3}He$ gas amount [$10^{-8}$ $cm^3$ STP/g] | | | |
|---|---|---|---|
| | $^{3}He$ | 1σ | 1σ [%] |
| Negrillos IIA | 13.22 | 0.21 | 1.59 |
| Cape of Good Hope IVB | 304.47 | 4.82 | 1.58 |
| Navajo IIB | 37.77 | 0.62 | 1.64 |
| Arispe IC | 118.52 | 6.70 | 5.66 |

**Table 1:** Cosmogenic $^{3}He$ amounts [$10^{-8}$ $cm^3$ STP/g]

**Further Work:** We have started to measure helium, neon, and argon in irradiated iron and nickel foils to determine cross sections for proton-induced reactions in the energy range relevant for modelling cosmogenic nuclide production in extraterrestrial matter. We will also measure helium, neon, and argon depth profiles in the Carbo iron meteorite. Additionally krypton and xenon will be analyzed in iron meteorites, as well as in their troilite inclusions. Combining all the data will enable us to establish purely physical model calculations for cosmogenic nuclide production in iron meteorites. Such a model is essential for detailed studies of GCR variations over timescales of hundreds of million years.

**References:** [1] Shaviv N. J. 2003. *New Astronomy* 8, 39-77. [2] Signer P. and Nier A. O. 1960. *J Geophys Res*, 65, No 9, 2947-2964. [3] Voshage H. 1984. *Earth and Planet Sci Lett* 71, 181-194. [4] Wieler R. 2002. *Rev Mineral Geochem* 47, 125-170. [5] Schultz L. and Franke L. 2004. *Meteoritic Planet Sci* 39, 1889-1890