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SOLAR NOBLE GASES REVEALED BY CLOSED SYSTEM STEPPED ETCHING OF A METAL SEPARATE FROM FAYETTEVILLE. Ch. Murer, H. Baur, P. Signer and R. Wieler, ETH-Zürich, NO C61, CH-8092 Zürich, Switzerland.

Abstract: Solar He, Ne, and Ar in a Fe-Ni separate from the chondrite Fayetteville are analysed by closed system stepped oxidation. We report here data of the first 15 steps comprising 55% of the total solar gases. $^4\text{He}/^{36}\text{Ar}$ and $^{20}\text{Ne}/^{36}\text{Ar}$ are quite constant at values about 20% below those of present day solar wind (SWC). In this, Fe-Ni differs from lunar ilmenites where $^4\text{He}/^{36}\text{Ar}$ and $^{20}\text{Ne}/^{36}\text{Ar}$ in the first steps are several times below SWC. Thus, metal retains SW-noble gases even better than ilmenite, almost without element fractionation. Nevertheless, the isotopic composition of SW-He, -Ne, and -Ar in the first steps of the metal sample are identical to those found in a recently irradiated lunar ilmenite, indicating that ilmenites and chondritic metal both contain isotopically unfractionated SW noble gases. A preliminary analysis of a smaller Fayetteville metal separate shows Ne from solar energetic particles (SEP-Ne) with $^{20}\text{Ne}/^{22}\text{Ne} \leq 11.5$.

Introduction: Diffusion coefficients for He, Ne, and Ar in metallic Fe-Ni are all similar and quite high (1). Therefore, trapped noble gases in Fe-Ni from gas-rich meteorites should reflect element and isotope abundances of the incoming solar corpuscular radiation even better than lunar ilmenites. We have thus extended our studies of solar noble gases by Closed System Stepped Etching (CSSE) to Fe-Ni separates. The CSSE technique is well suited to separate solar wind (SW) noble gases from solar energetic particles (SEP) which are implanted with energies above those of the SW.

Here we report data from a 0.5 g sized metal separate from the dark portion of the Fayetteville (H4-6) chondrite. The separate contained about 10 vol% silicates attached to the Fe-Ni particles. The sample was oxidised with increasingly aggressive $\text{CuCl}_2 \cdot x\text{H}_2\text{O}$ -solutions as first proposed by Vilcsek and Wänke (2). This reagent very selectively attacks only metal phases as tests have shown. Average procedural and reagent blanks for a typical step of one hour are (in $10^{-10} \text{ cm}^3 \text{ STP}$): $^4\text{He} = 500$; $^{20}\text{Ne} = 0.7$; $^{40}\text{Ar} = 100$. At the time of this writing, about 55% of the total ^{36}Ar of this sample have been released. We therefore also discuss the Ne isotopic data of a preliminary run on a 0.08 g Fe-Ni separate (3).

Element ratios: Fig. 1 shows $^4\text{He}/^{36}\text{Ar}$ and $^{20}\text{Ne}/^{36}\text{Ar}$ versus the cumulative fraction of ^{36}Ar . The first 3 steps had very short reaction times and are affected by noble gas element fractionation due to incomplete equilibration between gas- and liquid phase. Element ratios in all other steps are quite constant around the average values of: $^4\text{He}/^{36}\text{Ar} = 18560 \pm 4800$, $^{20}\text{Ne}/^{36}\text{Ar} = 38 \pm 4$ (standard deviation). These values are only slightly lower than those in the present-day solar wind (SWC: $^4\text{He}/^{36}\text{Ar} = 25650 \pm 5400$, $^{20}\text{Ne}/^{36}\text{Ar} = 45 \pm 10$, ref. 4). Constant $^4\text{He}/^{36}\text{Ar}$ and $^{20}\text{Ne}/^{36}\text{Ar}$ ratios close to SWC values were also found by stepped etching of a metal separate from the chondrite Acfer 111 (5). The element abundances in metal of Fayetteville and Acfer 111 thus remarkably differ from those in lunar ilmenite. The latter samples consistently display in the first CSSE steps $^4\text{He}/^{36}\text{Ar}$ and $^{20}\text{Ne}/^{36}\text{Ar}$ ratios several times below SWC values and approach SWC ratios only towards the end of a run, when mainly SEP gases are released (6,7,8). This indicates that even the most noble gas retentive mineral in lunar soils suffered a fractionating loss of light solar wind noble gases, though the SEP portion is retained with little or no fractionation. In contrast, chondritic metal shows little or no element fractionation even in the first CSSE steps, those which release SW gases.

The average $^4\text{He}/^{20}\text{Ar}$ and $^{20}\text{Ne}/^{36}\text{Ar}$ ratios of Fayetteville metal both are some 20% below those in Acfer 111 (5,9), the meteorite with the least fractionated solar noble gas composition in bulk samples yet reported. It is not yet clear whether the slight underabundance in Fayetteville metal of He and Ne relative to Ar and SWC ratios indicates a minor loss of He and Ne or some temporal variability in the SW composition. We found no evidence for $(^4\text{He}/^{36}\text{Ar})_{\text{sw}}$ as high as 36000 as postulated by (10) based on a stepped combustion analysis of a metal separate of the chondrite Weston.

He, Ne, Ar isotopes: Because of its quite unfractionated element patterns, the isotopic ratios of the first CSSE steps of the metal sample are of particular interest. Step 1 has a $(^{20}\text{Ne}/^{22}\text{Ne})_{\text{sw}}$ ratio of 13.9 ± 0.1 , followed by 4 steps where this ratio is between 13.65 and 13.85. These values are essentially identical to that of 13.8 for the $^{20}\text{Ne}/^{22}\text{Ne}$ ratio of SW-Ne retained in recently irradiated (<100 Ma) lunar ilmenite 71501 (6,7) and to the SWC ratio of 13.7 ± 0.3 (4). $(^{20}\text{Ne}/^{22}\text{Ne})_{\text{sw}}$ in Fayetteville metal and ilmenite from lunar soil 71501 are thus identical, though the ilmenite has lost a large fraction of its SW-Ne, whereas the metal may have retained its SW-Ne quite completely. This supports the conclusion that lunar ilmenites retain isotopically unfractionated SW-Ne (6,7).

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The time of exposure of Fayetteville to the solar wind (antiquity) is unknown. Notions that gas-rich meteorites may have acquired their solar noble gases early in solar system history have never been substantiated. In view of high collision rates in the asteroid belt we rather believe that asteroidal regoliths may be young, such that Fayetteville and lunar soil 71501 may be of comparable antiquity.

In both runs here $^{20}\text{Ne}/^{22}\text{Ne}$ decreases with progressive etching. This pattern is common to all CSSE runs on regolithic samples and indicates the release of SEP-Ne which is isotopically heavier than SW-Ne (e.g.6,7,8,11). Towards the end of the preliminary run $(^{20}\text{Ne}/^{22}\text{Ne})_v$ ratios are as low as 11.5, close to the SEP value of 11.3. We thus could isolate rather pure SEP-Ne from Fayetteville metal. Hence, not only does this phase release SW-Ne with an isotopic composition identical to that in lunar ilmenite but it also contains an SEP-Ne component very similar to that found in plagioclase, pyroxene, and ilmenite (6,7,11). To variable degrees, the latter minerals are all more prone to SW noble gas diffusion than Fe-Ni. The data here are thus an additional proof that the more deeply sited, isotopically heavier SEP-Ne component is not the result of diffusive alteration of surficially implanted SW-Ne, but indeed represents a real solar component implanted with higher energies than the solar wind. The complete data set of this ongoing run should also yield an improved ratio of the concentrations of SW- and SEP-gases.

The isotopic composition of Ar and He in the first steps of the 0.5 g sample are in good agreement with values previously deduced for the SW component (e.g.6,7,10). Due to cosmogenic Ar and He, the measured $^{36}\text{Ar}/^{38}\text{Ar}$ and $^3\text{He}/^4\text{He}$ ratios are lower than those of the solar component. A maximum correction for this can be done via cosmogenic ^{21}Ne , assuming that none of the $^{21}\text{Ne}_{\text{cos}}$ has recoiled from adjacent silicates. In the first 3 steps, the maximum correction ranges between 0.2 and 3% for $(^{36}\text{Ar}/^{38}\text{Ar})_{\text{meas}}$ and 0.8% for $(^3\text{He}/^4\text{He})_{\text{meas}}$. The resulting $(^{36}\text{Ar}/^{38}\text{Ar})_{\text{sw}}$ ranges between 5.47 and 5.58, the average $(^3\text{He}/^4\text{He})_{\text{sw}}$ is $(4.50 \pm 0.07) \cdot 10^{-4}$.

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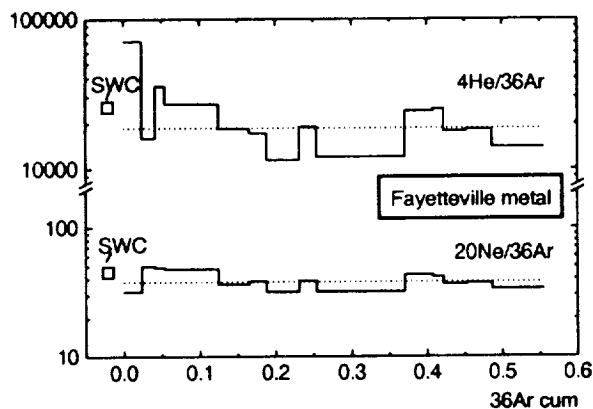


Fig. 1: $^4\text{He}/^{36}\text{Ar}$ and $^{20}\text{Ne}/^{36}\text{Ar}$ are rather constant and $\sim 20\%$ below the present-day solar wind (SWC, ref. 4). This indicates that Fayetteville metal shows little or no element fractionation even in the outermost, solar wind bearing grain layers.

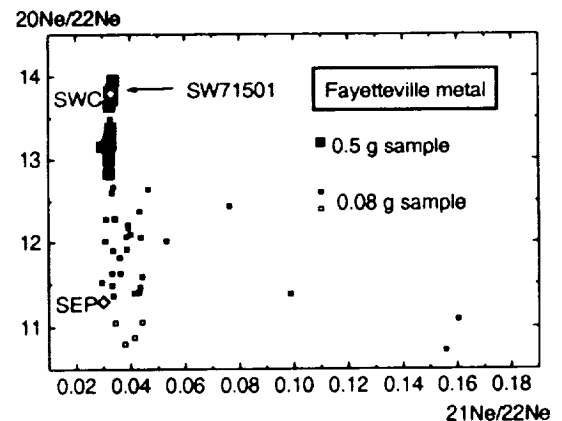


Fig. 2: Ne three-isotope plot. SW-Ne in Fayetteville metal is identical to that in recently irradiated lunar ilmenite 71501 (6,7) and to SWC (4). The SEP-Ne component is very similar to that found in plagioclase, pyroxene and ilmenite (6,7,11). Steps of the small sample shown by open symbols could not be measured accurately (uncertainty $> 5\%$). These data agree within error limits with the SEP composition.