PRELIMINARY GENESIS BULK SOLAR WIND AR, KR, AND XE ABUNDANCES IN COMPARISON TO YOUNG LUNAR REGOLITH AND SOLAR PHOTOSPHERE DATA.

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Introduction: A major objective of GENESIS is to constrain the present day solar wind (SW) Ar, Kr, and Xe isotopic and elemental compositions by direct measurements of SW irradiated artificial samples [1]. Due to the low abundances of heavy noble gases in the SW, until now these compositions could only be inferred from regolith samples which were irradiated by the SW over large time spans [e.g., 2-4]. Analysis of Genesis samples is more challenging due to the small amounts of heavy noble gases accumulated in the targets during the only 853 days of SW exposure. On the other hand, the interpretation of Genesis data should be more straightforward than that of regolith samples due to the lack of further major noble gas reservoirs and better controlled fractionation processes during ion implantation in Genesis targets.

Here, our preliminary new Genesis SW data will first be compared to data from "young" lunar regolith samples (having acquired SW during the last ≤100 Ma) [3-5]. It has been postulated [3-5] that such samples carry elementally and isotopically unfractionated "modern" SW Ar, Kr, and Xe at the very grain surfaces. This can now be tested with the new Genesis data.

Second, the Genesis data will be compared with the solar photospheric heavy noble gas composition. This is of major importance in order to better understand and quantify fractionation processes between the Sun and the SW, e.g., the so-called FIP-fractionation (see below). This will finally serve to better constrain solar system elemental and isotopic abundances, which in turn allow ruling on the composition of the solar nebula.

Samples, Data: So far, 5 aliquots of Czochralski-grown Si targets exposed to the bulk SW have been analyzed. Results have been presented in abstracts by Heber et al. [6, 7] and are listed below.

Noble gases were extracted from areas between 10 to 50 mm^2 by UV laser ablation (213 nm). Ar, Kr, and Xe were analyzed together after gas purification using a cold trap (-78 °C) and several getters. One analysis was compromised by memory effects and is thus excluded. Preliminary average isotopic and elemental ratios from the remaining 4 analyses are $^{86}Kr/^{84}Kr$ = 0.3037, $^{129}Xe/^{132}Xe$ = 1.037, $^{36}Ar/^{84}Kr$ = 2484, and $^{84}Kr/^{132}Xe$ = 9.5. Fig. 1 a-d shows these results in comparison to SW data deduced from "young" lunar regolith samples and solar photospheric values. SW fluences over the entire exposure duration in atoms/ cm^2 are about 2.97 x 10^{10} for ^{36}Ar, 1.20 x 10^7 for ^{84}Kr, and 1.3 x 10^6 for ^{132}Xe [6, 7]. We anticipate presenting a larger dataset at the conference.

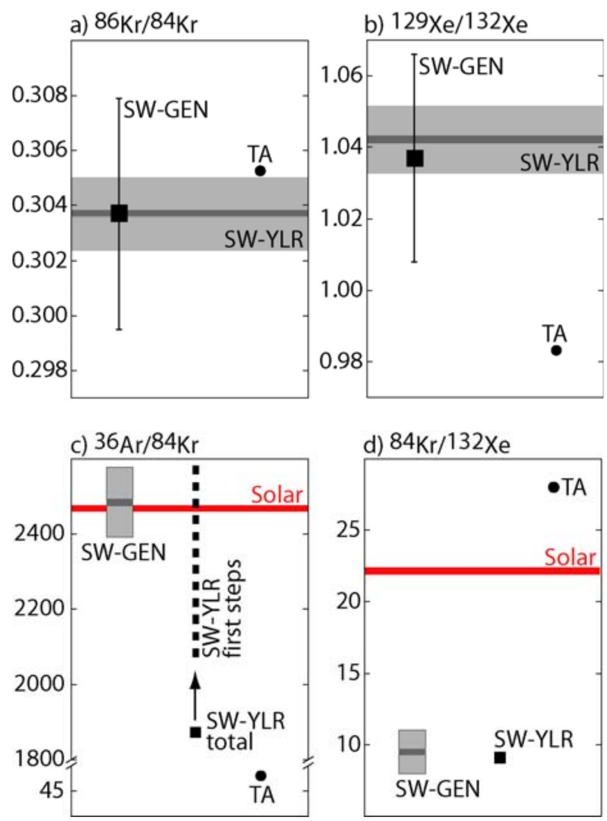

Fig. 1: Preliminary heavy noble gas isotopic and elemental compositions of SW measured in Genesis ("SW-GEN") targets in comparison to SW deduced from "young" lunar regoliths ("SW-YLR") and solar photospheric ratios ("Solar"). See text for references. Also given are terrestrial atmospheric ratios ("TA") [8]. Uncertainties given for the Genesis data are the standard deviations of the four analyses.

Discussion: In the following we will compare the Genesis data with those deduced from recently irradiated lunar regolith samples [3, 4]. Basically, the Genesis and lunar regolith SW isotopic and elemental ratios are both in good agreement with each other. A deviation from this general observation in the $^{36}Ar/^{84}Kr$ ratio will be addressed below.

Isotopic ratios. Both the Genesis SW $^{86}Kr/^{84}Kr$ and $^{129}Xe/^{132}Xe$ isotopic ratios are in good agreement with SW deduced from the very first etch steps of an ilmenite separate from lunar soil 71501 (Fig. 1a, b). The larger uncertainties of the Genesis data are mainly due to the very low gas amounts and substantial material blank levels. We expect that a larger data set will improve precision.

Elemental ratios. The average Genesis SW elemental ratio $^{84}Kr/^{132}Xe$ of ~9.5 is in remarkable agreement with SW ratios deduced from samples 71501 (~9.0) and 67601 (~8.4) (Fig. 1 d) [4, 5]. As solar photospheric abundance values we adopt here the elemental ratios given in [9]. The photospheric $^{84}Kr/^{132}Xe$ ratio of 22 is essentially identical to the older value of 21 [10]. It follows that the SW is enriched in ^{132}Xe relative to ^{84}Kr by a factor of ~2.3 compared to the solar photosphere. The same degree of enrichment (factor of ~2.3) had been postulated based on the lunar data [4, 5].

The Genesis SW $^{36}Ar/^{84}Kr$ ratio of ~2480 is virtually identical to the solar photospheric value of ~2470 adopted here (Fig. 1c). This value is based on the photospheric Kr abundance given in [9] and the Ar abundance recommended by [11]. The latter represents the average of Ar abundances from various stellar and planetary environments and a nuclear semiequilibrium value. We prefer this $^{36}Ar/^{84}Ar$ ratio to the distinctly lower $^{36}Ar/^{84}Kr$ of ~1200 given by [12] who dramatically reduced the photospheric Ar abundance, but left Kr and Xe unchanged.

While the new Genesis SW $^{36}Ar/^{84}Kr$ and the adopted photospheric ratios agree very well, the published SW $^{36}Ar/^{84}Kr$ ratio deduced from the lunar soil 71501 of ~1870 [4] is ~25% lower than the former ratios. This apparent deviation might be significantly reduced if the lunar SW $^{36}Ar/^{84}Kr$ ratio would be deduced from the very first etch steps only rather than from the total gas concentrations – just as it is done for determining the lunar SW isotopic ratios. Indeed, the two first etch steps, comprising ~40% of the total ^{36}Ar released, show much higher $^{36}Ar/^{84}Kr$ ratios of 2050 and 2580. Unlike the rather uniform lunar regolith $^{84}Kr/^{132}Xe$ ratios, the lunar $^{36}Ar/^{84}Kr$ ratios monotonously decrease with progressive etching, which might indeed justify the use of only the first etch steps instead of the total gas amounts.

Fractionation of noble gases between Sun and Solar Wind: During ion-neutral separation in the upper chromosphere elements are fractionated for example according to their first ionization potential (FIP) or their first ionization time (FIT), such that low-FIP or low-FIT elements get enriched in the SW (see, e.g., [13] and references therein).

As already postulated by [4, 5] based on lunar samples, the Genesis data indicate an enrichment of Xe relative to Kr in the solar wind by a factor of ~2.3.

In contrast, the new Genesis SW $^{36}Ar/^{84}Kr$ ratios agree well with the solar photospheric values adopted here, arguing against a Kr enrichment in the SW. This finding is in line with the general observation that formerly published FIP fractionation factors [e.g., 13] have recently been corrected downwards [e.g., 14, 15]. However, the finding of an unfractionated SW $^{36}Ar/^{84}Kr$ ratio differs from [4], who postulated a partial enrichment of Kr over Ar in the SW. As discussed above, this apparent deviation between Genesis and lunar data might be related to the selection of etch steps of the lunar data set rather than to real differences between both data sets.

The fractionation factors given here of course depend on the adopted elemental abundances in the solar photosphere, which are model dependent and thus might be subject to further changes. Yet, these first Kr and Xe data from Genesis are basically confirming the overall picture of an elemental fractionation of heavy noble gases between sun and solar wind inferred earlier from lunar and meteoritic data.

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