

REEVALUATION OF THE SOLAR WIND $^{36}\text{Ar}/^{38}\text{Ar}$ RATIO; R. H. Becker¹, D. J. Schlutter¹, P. E. Rider², and R. O. Pepin¹, ¹School of Physics and Astronomy, University of Minnesota, Minneapolis, MN 55455, ²Department of Physics, Grand View College, Des Moines, IA 50316.

The isotopic composition of solar wind (SW) argon is an important parameter in the modeling of the evolution of the terrestrial planet atmospheres [1,2]. Anders and Grevesse [3] assumed a $^{36}\text{Ar}/^{38}\text{Ar}$ ratio for SW of 5.31, essentially equal to that of air. Considerable evidence has since developed which indicates that this ratio is too low [4-7]. Benkert et al. [7] have reported their best estimate for the recent SW as 5.48 ± 0.05 , determined from measurements of lunar soil 71501. Based on Ar data obtained from surface oxidation of a metal separate from the Weston meteorite and from an uncontrolled etch of lunar sample 67701, reported by our group previously [4,6], we consider even this value to be too low. Since values of 5.75 to 5.85 were reported by Black [8] for initial low temperature (<150C) pyrolysis steps on samples of Kapoeta, which, even allowing for diffusive fractionation, imply a fairly high SW $^{36}\text{Ar}/^{38}\text{Ar}$ ratio (in the range of ~5.6 to ~5.7), we decided to analyze Kapoeta for its light solar wind gases using the acid-etching techniques developed in our laboratory [9] based on the CSSE procedure of Benkert et al. [7].

A 208.3 mg sample of Kapoeta was gently crushed and sieved, and the <250 μm portion was taken for analysis. The sample was loaded in an Inconel finger in the system described in [9], and after three water washes, which brought the $^{40}\text{Ar}/^{36}\text{Ar}$ ratio down to 2.9 from an initially atmospheric value, it was etched with gradually strengthened H_2SO_3 solution for varying lengths of time at room temperature over a dozen steps, and then for another 6 steps at 75C-80C. Finally, a series of pyrolysis steps was carried out to extract as much of the gases remaining in the etch residue as possible given the relatively low maximum pyrolysis temperature (~1150C).

Results of the analysis for argon are given in Fig. 1 in terms of the $^{36}\text{Ar}/^{38}\text{Ar}$ ratio as a function of the fraction of total argon released. All steps are shown in Fig. 1. Steps corresponding to water washes and to pyrolyses are shaded to distinguish them from the actual etch steps. By going to higher etch temperatures than in earlier work [9], we were able to release about 90% of the total Ar in the sample by etching, comparable to results for ilmenites using HF [7]. Also shown on Fig. 1 is the best estimate of Benkert et al. [7] for SW $^{36}\text{Ar}/^{38}\text{Ar}$, with its uncertainty. Excluding the three water wash steps, the first two of which are dominated by air argon, the initial 11% of the Ar released lies essentially outside the uncertainty given by Benkert et al. [7]. Cumulatively, this fraction of the argon has a $^{36}\text{Ar}/^{38}\text{Ar}$ ratio of 5.58 ± 0.03 . This is in good accord with a value of 5.61 reported by Pedroni [5] for the first 12% of Ar released by etching from a plagioclase separate from Kapoeta. Further releases in Pedroni's sample were compromised by the apparent presence of spallogenic argon, whereas with the weaker acid and more complex mineralogy of our sample the argon remained close to the SW end-member for a further 20% of the argon release. The absence of significant spallogenic gas release is confirmed by our Ne results, wherein the $^{21}\text{Ne}/^{22}\text{Ne}$ ratio does not exceed 0.034 over the first third of the Ar release.

A comparison of the $^{36}\text{Ar}/^{38}\text{Ar}$ ratios with $^{20}\text{Ne}/^{22}\text{Ne}$ ratios (Fig. 2) can also be taken to indicate that spallogenic argon is not a significant factor in our data. What one sees in Fig. 2 is a general trend parallel to but lying below a line that would connect either Benkert et al. [7] SW end-member, but in particular the one from 71501, with a Solar Energetic Particle (SEP) end-member as defined by them. An SW $^{36}\text{Ar}/^{38}\text{Ar}$ ratio of 5.6 would provide a mixing line that more closely fits the bulk of the data points. (Two of the three points significantly below the bulk of the data are from pyrolysis steps, and may be subject to both diffusive fractionation effects during gas extraction and to the presence, primarily in the Ne, of a spallogenic component released above 600C.) It should be noted that the bulk sample Ne/Ar ratio in Kapoeta is about a factor of 2 below the solar ratio, so that the reason we do not see the expected SW $^{20}\text{Ne}/^{22}\text{Ne}$ ratio of 13.8 may be due to a diffusive fractionation that occurred during loss of the Ne. This could also explain the tendency of the data points to lie somewhat below the SW-SEP mixing line, but would not account for $^{36}\text{Ar}/^{38}\text{Ar}$ ratios in Fig. 2 which lie to the right of the Benkert et al. [7] values.

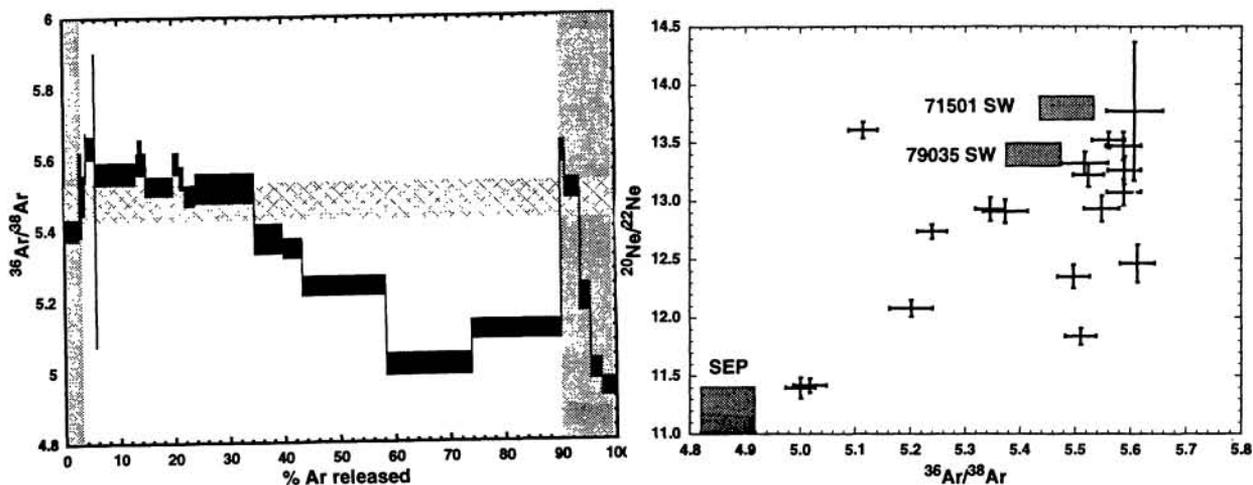
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Fig. 1 (left). $^{36}\text{Ar}/^{38}\text{Ar}$ ratio vs. % of argon released for all steps done on Kapoeta <250 μm . Shaded region on the left shows water washes, shaded region on the right shows pyrolysis steps. Horizontal hatched area indicates best estimate of recent solar wind from [7]. **Fig. 2 (right).** $^{20}\text{Ne}/^{22}\text{Ne}$ vs $^{36}\text{Ar}/^{38}\text{Ar}$ for all steps excluding water washes and one step with very small gas amounts. Shaded boxes are values given for SEP, SW from 79035 ilmenite and SW from 71501 ilmenite in [7]. 71501 is assumed to represent recent solar wind, 79035 solar wind at some time in the past $>10^9$ years ago.

A curiosity in Fig. 1 is the observation that the initial pyrolysis steps (at 200C and 400C) return to a $^{36}\text{Ar}/^{38}\text{Ar}$ ratio very close to that seen in the initial acid etch steps. This would be difficult to explain in terms of diffusive fractionation from a reservoir such as that being tapped by the last acid etches. It is possible that there is an acid-resistant but thermally labile phase present which retains a mostly unaltered SW reservoir of argon that we are seeing in these steps. However, the Ne associated with these argon values is well below solar (12.5 and 11.8 at 200C and 400C, respectively), so it is not as simple as having a totally unaltered solar reservoir present. At the moment, the phenomenon is not understood.

We would thus conclude on the basis of the data presented here, in conjunction with the earlier data showing $^{36}\text{Ar}/^{38}\text{Ar}$ ratios in the vicinity of 5.6 [4-6], that such a ratio is more appropriate for the SW $^{36}\text{Ar}/^{38}\text{Ar}$ ratio over much of the time period when lunar and meteoritic samples acquired their solar gases than the value of 5.48 put forward by Benkert et al. [7].

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