A COMPARISON OF SOLAR WIND AND SOLAR SYSTEM XENON ABUNDANCES

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A detailed knowledge of the elemental abundances in the solar system is crucial to our understanding of its origin and evolution. Abundances of the volatile elements cannot be determined from CI chondrites. Xe and Kr abundances are usually obtained by interpolation from surrounding elements, taking advantage of the observed smoothness of the odd A abundance curves. However, the identification of solar abundances with these interpolations makes the assumption--possibly invalid--that the sun and the solar nebula incorporated gas and dust in exactly the same relative proportions as in the initial interstellar cloud. A comparison of photospheric or solar wind (SW) volatile abundances with their CI-interpolated abundances can constrain the extent of possible solid/gas fractionation in the early solar nebula. This was done recently for Kr [1]. The SW Kr/Si ratio was estimated via a combination of spacecraft detector data and apparently unfractionated low-temperature oxidations of SW-rich lunar ilmenite grains [2,3]. The estimated solar ^{83}Kr abundance of 4.1±1.5 per 10^6 Si atoms is within uncertainty of CI interpolation estimates, though the large uncertainty only confines possible solid/gas fractionation to somewhat less than a factor of two.

For Xe interpolation is more difficult because Xe constitutes an r-process peak, and cannot simply be matched between odd-mass abundances on either side as with Kr. Fortunately, contemporary s-process theory provides an excellent quantitative fit (20-30% or better) for s-only nuclei in the mass range 100-200, and this provides a reliable estimate of the abundance of s-only ^{130}Xe. A couple of other potential difficulties with Xe deserve mention: If the sun were depleted in solids formed at low T, Xe might behave partially as an involatile element, and any solid/gas fractionation evident from xenon would be a lower limit for more-volatile species. Another difficulty is the possibility of secular variations of SW Xe abundances [3,4], which could completely throw off any solid/gas fractionation estimates based on SW xenon. This will be touched on later.

Briefly, the SW Xe abundance is determined in the following manner: the low-temperature ilmenite oxidations give ^{130}Xe/^{20}Ne and ^{130}Xe/^{36}Ar ratios, which are normalized to Si using the Apollo SW foil ratio ^{20}Ne/^{36}Ar = 0.0205±.0050 [5,6] and spacecraft detector ratios of Ne/O = 0.17±.02 [7,8] and Si/O = 0.19±.04 [8]. The data and results are shown in Table 1 for ilmenite separates of 71051 and also 79035, a more ancient soil [10,11]. The SW ^{130}Xe abundances are well below solar system abundance estimates [12,13], but the simplest explanation for this difference is that SW Xe is also fractionated relative to the photosphere. Such fractionation afflicts all observed elements with first ionization potentials (FIPs) greater than ~ 10 eV. The factor is uncertain but should be well within a conservative estimate of 4.2±1.5 [1].

Table 2 contains solar system Xe abundance estimates based on s-process systematics and interpolations [12,13]. An additional constraint comes from even-odd abundance considerations. Odd-mass nuclei in a given mass range are always less abundant than the even ones. The abundances of ^{128,130}Te from CI chondrites form a firm upper bound on the average non-radiogenic solar system ^{129}Xe, translating to a maximum ^{130}Xe abundance of 0.29 (Si≡10^6).

The SW results have been added to Table 2 after correction for photospheric fractionation. The more recently exposed ilmenite (71051) is nearly identical to the CI interpolated and s-process estimates. This data, as well as Kr results [1], indicate that within uncertainties, gas and dust were captured by the sun in proportions representative of the solar nebula bulk composition. Although errors (dominated by uncertainties in the fractionation factor and SW Si) overlap, the 79035 datum appears out of line with cosmic Xe abundance estimates with a nominal value above the even-odd constraint. Because of its magnitude (a factor of 1.6 greater) and because the higher relative Xe abundance persists in the high temperature fraction [3], it is unlikely that this is simply an artifact of a previous regolith exposure cycle from which the Xe diffused slower than the other gases.

Assuming that the xenon anomaly in 79035 is due to the SW, the even-odd abundance constraint indicates that either all elements in the Xe mass region were enhanced in the SW or, more likely, the fractionation factor was modified. The Xe FIP, at 12.1 V, is the lowest of the noble gases, and thus the most likely to be altered by a change in the SW ionization mechanism. Such a change should also affect several other elements, including C, although these would be very difficult to detect in ancient lunar soils. If such changes occur, it is not possible to know for sure that the SW trapped in the apparently more-recent soil 71501 is the same as the present-day SW.

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TABLE 1. Data used for calculation of the SW ^{130}Xe abundances. Ilmenite data from [2,3]; SW ^{20}Ne/Si and ^{36}Ar/Si data from [5,6,7,8,9].

Sample	---------Ilmenites---------		Directly Measured SW		^{130}Xe
	^{130}Xe/^{20}Ne	^{130}Xe/^{36}Ar	^{20}Ne/Si	^{36}Ar/Si	(Si≡10^6)
71501	6.82×10^{-8} ±.31		0.83 ±.20		0.057 ±.014
71501		3.11×10^{-6} ±.21		0.0183 ±.0063	0.057 ±.020
79035	1.09×10^{-7} ±.13		0.83 ±.20		0.090 ±.024
79035		5.05×10^{-6} ±.45		0.0183 ±.0063	0.092 ±.033

TABLE 2. Abundance estimates of ^{130}Xe from near-element CI interpolations, s-process systematics, and even-odd abundance considerations, along with solar wind fractionation-corrected abundances from the lunar ilmenites and spacecraft data given in Table 1.

Source	^{130}Xe
Anders and Grevesse [12]	0.21
S-process [13]	0.22±.09
Even-odd abundances	≤0.29
71501 Ilmenite	0.24±.09
79035 Ilmenite	(0.38±.14)