ARE ISOTOPICALLY SOLAR COMPONENTS PRESENT IN HEAVY NOBLE GASES FROM TERRESTRIAL MANTLE SAMPLES? PERHAPS... R. O. Pepin, School of Physics and Astronomy, University of Minnesota, Minneapolis, MN 55455.

Evidence for a solar-like $\text{He}/\text{Ne}$ component in mantle-derived basalts, diamonds, and well gases has been reported by Honda et al. [1,2]. An issue of considerable importance for the sources, incorporation mechanisms, and transport of primordial noble gases in the Earth is whether signatures of isotopically solar components also exist in Ar, K, and Xe. Elemental abundances of these heavy gases relative to $\text{Ne}$ are $\approx 5$ orders of magnitude higher than the corresponding solar ratios, attributable in part to addition of atmospheric gases by seawater-magma interaction [3], subduction [4], or both. Their nonradiogenic isotope ratios are generally considered to be indistinguishable from those in air [2,5-7]. The intent here is to examine the constraints imposed by the current data set of heavy-gas isotopic measurements on the presence and relative magnitudes of solar-composition components in the mantle.

Argon. ($^{36}\text{Ar}/^{38}\text{Ar}$) ratios have been measured in MORBs [5], Loihi sample suites I [5] and II [2], Kilauea glasses [2], diamonds [6], and Samoan xenoliths [7]. Of note in Fig. 1 is the displacement of many of the OIB data (e.g. Loihi II, Savai’i/PPT (Samoan) xenoliths) downward from air toward the ($^{36}\text{Ar}/^{38}\text{Ar}$$_0$) range ($\sim$0.175-0.182 [8]).

![Figure 1](https://example.com/figure1.png)

Estimates of solar Ar contents follow from combining Ne and Ar data. Measured ($m$) Ne is a mixture of solar ($s$) and air (a) constituents: $^{22}\text{Ne}_m^s = [22\text{Ne}_m^s/22\text{Ne}_m^a]_{\text{Prim}} \cdot [22\text{Ne}_m^s/22\text{Ne}_m^a]_{\text{Prim}}$. The abundance of the solar component. (A crude correction for bubble formation fractionation [3] and post-eruptive Ne loss was applied to all but the diamond data by adjusting $^{22}\text{Ne}_m^s$ such that $F_{22} = [22\text{Ne}_m^{22}\text{Ar}]_a/[22\text{Ne}_m^{22}\text{Ar}]_s = 1$, the value calculated for magma-seawater equilibration [3]; this has little effect, however, on the Figs. 2 and 3 distributions discussed below). Solar $^{36}\text{Ar}$ is then $^{36}\text{Ar}_m^s = [36\text{Ar}_m^s/36\text{Ar}_m^a]_{\text{Prim}} \cdot [36\text{Ar}_m^s/36\text{Ar}_m^a]_{\text{Prim}}$ where $^{36}\text{Ar}_m^s$ is the solar-wind ratio ($\approx 0.30$ [9]). The factor $F_{22}$ takes into account possible Ar/Nel elemental fractionation from $^{36}\text{Ar}_m^s$ before or during initial incorporation of solar gases, or during later transport within the planet. Assuming no transport fractionation [4], mantle $F_{22}$ would be $\approx 1$ for SW implantation into proto-Earth materials, and $\approx 30$ for adsorption of nebular gases onto Earth’s planetary embryo [8] or in accretional matter, if this occurred with the mean adsorption fractionation seen in laboratory experiments (summarized in [8]). With these two equations, the predicted $^{36}\text{Ar}/^{38}\text{Ar}$ ratio is readily expressed as $^{36}\text{Ar}_{m \text{calc}} = (^{36}\text{Ar}/^{38}\text{Ar})_s - [^{36}\text{Ar}/^{38}\text{Ar}]_a \cdot [^{34}\text{Ar}/^{38}\text{Ar}]_s - (^{36}\text{Ar}/^{38}\text{Ar})_a$.

Fig. 2 depicts the differences between measured and calculated values of $^{36}\text{Ar}/^{38}\text{Ar}$. For $F_{22} = 1$, calculated and air ratios differ by $\leq 2\%$, so Fig. 2A is just a rescaled version of Fig. 1. Thus a primordial Ar component implanted by solar wind and elementally unfractonated by transport would be isotopically invisible in these sample suites, and would remain so even with much greater analytic precision. Not so with $F_{22} = 30$ (Fig. 2B), where many of the low ratios in Fig. 1 are now closer to calculated values. Note, however, the increase in the number of positive discrepancies. Some explanation for these is needed to accommodate $F_{22}$ as high as 30. One possibility, subject to test, is suggested by the Fig. 3 plot of analyzed $^{40}\text{Ar}$ abundances vs. significant (210)$^{40}\text{Ar}$ excesses, which tend to appear when $^{40}\text{Ar}$ in the mass spectrometer exceeds $10^4$ ccSTP, and when $^{40}\text{Ar}/^{38}\text{Ar}$ ratios are in the range $<10^4$ to $>10^5$. The line slopes $\lambda$ indicate that $-0.02$ to sub-ppm-level variations in the mass rejection of 40 at 38 under these analytic conditions could, if undetected, account for the observed enhancements (up to $-7.5\%$) in measured $^{36}\text{Ar}/^{38}\text{Ar}$.

Xenon and Krypton. There are two hints of solar signatures in Xe isotopic data. The first is a $^{130}\text{Xe}/^{132}\text{Xe}$ ratio $<20$ above the air value in a well gas [10], implying an $-8\%$ solar component [2,4]. Well-gas Xe and associated Ne data yield $f_{76} = [^{130}\text{Xe}/^{132}\text{Xe}]_m / [^{132}\text{Xe}/^{132}\text{Xe}]_m = 1800 \pm 1300$. The second appears in the diamonds [6] in $^{128}\text{Xe}/^{132}\text{Xe}$ and also in $^{128}\text{Xe}/^{130}\text{Xe}$. Individual measurements of these 3 ratios in the diamond suite all have errors overlapping air but are consistently high; treated statistically, they yield a solar $^{132}\text{Xe}$ mixing ratio of $50 \pm 20\%$ and, together with Ne data, an average $f_{76}$ of $5900 \pm 2200$ in 7 of the 10 samples (2 others have clearly lost Ne). These two $f_{76}$ values.
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overlap at the 2σ level and lie well within the data field for laboratory adsorption [8]; if verified they point to initial incorporation of mantle solar gases by adsorption, or to large transport fractionation. Solar signatures will be extraordinarily difficult to see in the Kr isotopes. The implied f^{80} and f^{38} values above suggest f^H ≤ 350 [8]; with this a solar component would comprise ≤7% of the 84Kr in the diamond suite. The corresponding enhancement in 78Kr/84Kr, the solar-wind ratio most different (+45‰ [11]) from air (and most difficult to measure), would be ≤3‰.

Conclusion. There is no unambiguous isotopic evidence as yet for solar Ar and Xe components in these samples, but some data do suggest their presence. Higher analytic precision will be needed to answer this question.