Terrestrial Xe isotope systematics and the missing Xe problem can be resolved in a model of Giant Impact-related atmosphere loss

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Compared to the other noble gases on Earth, Xe is less abundant than expected in a fractionated primordial source (by a factor 2-4 if the source is solar, and 10 if it is "Q" gas; the "missing Xe problem"). Also, terrestrial Xe is much more strongly fractionated than lighter Kr. These perplexing features correspond to each other, and both show that Xe records a different atmosphere loss event from that seen in the lighter noble gases.

^{129}Xe(I) and ^{136}Xe(Pu) systematics require multiple (total or partial) atmosphere losses. The data are compatible with a first extensive loss at 50-60 Ma after solar system formation (SOS). We propose that this followed the Moon-forming Giant Impact. The implication for Giant Impact timing is not in conflict with Hf-W isotope data. First, existing cores of the impactor and the Earth mainly merged during this event [1], and second, not much Hf/W fractionation is expected to have taken place in their mantles [2]. Therefore the Hf/W date for the silicate mantles of Earth and Moon ~30 Ma after SOS [3] is a minimum time for the Giant Impact.

Terrestrial Xe fractionation, (exponential fractionation factor ~1.8) is low compared to what is predicted from pure Jeans escape from the Earth, even with >80% loss at high temperature (10000 K). A combination of hydrodynamic escape and Jeans escape must be invoked. Regardless, the light noble gases as well as major volatile elements would be lost in this process. Lighter noble gases are however more soluble in silicate magma than Xe. Using the concept of a hot atmosphere in equilibrium with a magma ocean we propose, similar to [4], that Ne, Ar and Kr were replenished from such a magma ocean as it solidified. Further accretion after the Giant Impact supplied the major atmospheric components, and later hydrodynamic partial atmosphere escape caused isotope fractionation of Ne, but not of Kr and Xe. This model reconciles radiogenic and stable noble gas isotope systematics and resolves the missing Xe paradox.

References

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