Sequestration of Xe in an early, hydrous Martian crust

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The modern Martian atmosphere preserves an apparent paradox: ^{129}Xe, produced by the decay of ^{129}I ($t_{1/2}$=16 Myr), is abundant, whereas the later produced isotopes from ^{244}Pu fission ($t_{1/2}$=80 Myr) are nearly absent [1]. Recent work has shown that H_2O and possibly CO_2 from degassing of the Martian magma ocean can cause significant aqueous alteration of the early crust and form phyllosilicates which can survive to the present day [2,3]. Studies have shown that noble gas solubility correlates with ring sites in mineral structures, including phyllosilicates, and that phyllosilicates have high noble gas solubilities compared to other common silicates [4-6]. Thus, significant amounts of Xe could be sequestered in an early, hydrated Martian crust when $^{129}Xe_I$ was abundant, but before substantial Xe_{Pu} was produced.

A box model was developed to assess the extent to which Xe could be sequestered in the early crust. Initial I, U, and Pu contents and isotopic ratios were back-calculated from modern Bulk Silicate Mars and the ^{129}I/^{127}I ratios of C3 chondrites [7-10]. Decay products of ^{129}I and ^{244}Pu were calculated for a 70-100% degassed mantle 40 Myr after solar system formation, around the time of crustal differentiation [11], with all Xe from the first 10 Myr assumed to be lost during accretion. In the most conservative case, a 15-20 cm thick global equivalent layer of primordial phyllosilicates can sequester all of the ^{129}Xe that is now in the atmosphere while also trapping only 0.4% of the modern ^{136}Xe. In combination with mass-dependent fractionation from hydrodynamic escape, sequestration of Xe in phyllosilicates can explain how the earliest produced Xe isotopes were retained while the later produced isotopes have been lost, and is consistent with observations of the modern atmosphere.

[1] Conrad et al. (2016), *EPSL* 454, 1-9. [2] Elkins-Tanton et al. (2008), *EPSL* 271, 181-191. [3] Cannon et al. (2017), *Nature* 552, 88-91. [4] Jackson et al. (2015), *GCA* 159, 1-15. [5] Jackson et al. (2013) , *Nat. Geosci.* 6, 562-565. [6] Krantz et al. *in prep*. [7] Dreibus & Wänke (1985), *Meteoritics* 20, 367-381. [8] Hudson et al. (1989), *LPS XIX 547-557*. [9] Crabb et al. (1982), *GCA* 46, 2511-2525. [10] Porcelli et al. (2002), *RIMG* 47, 1-19. [11] Kruijer et al. (2017), *EPSL* 474, 345-354.