Noble gas geochemistry of Venus and other terrestrial planets

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The elemental and isotopic composition of noble gases in the atmosphere of Venus was measured in the late 1970s by Pioneer Venus and various Venera missions. While these reconnaissance data are immensely valuable, they are incomplete and rather imprecise. Furthermore, direct information on the noble gas composition in the interior of Venus is completely lacking. In contrast, for Mars some information on interior (and atmospheric) noble gases is available from Martian meteorites, in addition to the Viking data on Mars' atmosphere. Nevertheless, important first order comparisons between the noble gas inventories of the three large terrestrial planets can be made.

Radiogenic noble gas isotopes in their atmospheres constrain the degassing history of the terrestrial planets. The ^{40}Ar inventory in Venus' atmosphere normalized to the planet's mass is about 2 - 5 times lower than the value for the Earth, strongly suggesting a less efficient degassing of Venus throughout its history. It is thought that this is related to the different tectonic regimes of the two planets. While raidogenic ^{129}Xe from short-lived ^{129}I (half-life 15.7 Ma) in both the Terrestrial and Martian atmosphere indicate an almost complete degassing of the planets within the first 100 Ma, no respective information is available for Venus.

The relative abundances of the non-radiogenic noble gases in all three terrestrial planet atmospheres to first order resemble each other. They are also somewhat similar to abundance patterns in primitive meteorites, with light gases - especially Ne and Ar - being strongly and progressively depleted relative to heavier gases and solar elemental composition. Isotopic data indicate, however, that the crude similarity of planetary and meteoritic patterns cannot straightforwardly be explained by "gas-poor" noble gas acquisition scenarios, where noble gases in planets derive from sources similar to known present-day meteorite classes. "Gas-rich" models are more prominent today, postulating that the planets initially accreted large noble gas amounts of probably solar-like composition. A variety of subsequent loss processes have been postulated, allowing modellers to chose among a variety of processes potentially able to fractionate elemental and isotopic ratios. Important in this context is that the Ar-Kr-Xe abundance pattern in Venus' atmosphere is considerably less fractionated relative to solar composition than in the case of Earth and Mars, and that Venus also contains one to two orders of magnitude more Ne and Ar in its atmosphere than does the Earth. A popular mechanism to explain early loss of atmospheric noble gases is hydrodynamic escape, where the abundant hydrogen in a primordial atmosphere is heated, e. g. by solar UV, and upon escaping drags heavier species along.