The evolution of the isotopic composition of the atmosphere through time

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Recent studies have demonstrated that old atmospheric xenon trapped in fluid inclusions of Archean samples is isotopically intermediate between potential primordial end-members (chondritic or solar) and the modern atmosphere [1] [2]. These preliminary results have been interpreted as resulting from a prolonged escape of Xe atoms from the atmosphere to the outer space [3]. This escape might be due to the ionization, isotopic fractionation and trapping of Xe atoms in organic matter [4] and could have lasted until the oxygenation of the Earth's atmosphere.

We have analyzed noble gases (Ne, Ar, Kr & Xe) and N_2 in fluid inclusions trapped in quartz of a wide range of ages (3.5 Ga to present) in order to get the precise evolution of Xe fractionation through geological periods of time, and to estimate the time when the current isotopic composition was established.

In quartz from the Barberton area (South Africa), the Archean (≈3.3 Gyr) Xe isotope ratios indicate an isotopic fractionation of 10.4 ± 0.78 ‰.amu^{-1} in favor of the lighter isotopes for the Archean atmosphere relative to the modern one. The fractionation is less severe for 2.7 Gyr-old quartz from the Fortescue Group (Australia) and reaches 8.5 ± 1.3 ‰.amu^{-1}. Finally there is almost no resolvable isotopic fractionation of Xe in 2.0 Gyr-old quartz (West Africa) with a value of 1.1 ± 0.9 ‰.amu^{-1}. More recent quartz contains Xe isotopically similar to the modern atmosphere for non-fissiogenic isotopes. Kr analysed precisely in all samples is isotopically normal. Neon (and N_2) isotopes do not reveal any mantle contribution.

We demonstrate in this study that there was a specific atmospheric process occuring in the Archean atmosphere that was responsible for the escape and isotopic fractionation of Xe isotopes. The curve of the evolution of the isotopic composition of atmospheric Xenon is now well established and might help to understand the long-term evolution of the atmosphere.

[1] Pujol *et al*. (2009) *GCA* **73**, 6834-6846 [2] Pujol *et al*. (2011) *EPSL* **308**, 298-306 [3] Marty (2012) *EPSL*, **313-314**, 56-66. [4] Hébrard & Marty (2014) *EPSL* **385**, 40-48.