Xenon in carbonaceous matter: a paleo-atmospheric proxy and a dating tool for paleo-fossils?

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Noble gases are key tracers of the origin and evolution of planetary atmospheres. On Earth, atmospheric xenon (Xe) presents two striking features. First, its abundance is lower than for a chondritic-like abundance pattern. This suggests that some Xe is missing from the Earth's atmosphere. Secondly, atmospheric Xe is enriched in heavy isotopes and depleted in light isotopes relative to cosmochemical end-members. These two features form the so-called "xenon paradox" [1]. Recent work demonstrated that the isotopic composition of atmospheric Xe evolved until ca. 2 Ga ago [*e.g.* 2-4]. This protracted isotopic evolution is evidence for a specific escape mechanism operating for Xe [5]. Under certain conditions, Xe ions could escape together with hydrogen ions in an oxygen-free atmosphere. The isotopic composition of atmospheric Xe would thus be an indirect tracer of the oxygenation of the Earth's surface [4]. A recent study also proposed to use the isotopic composition of Xe trapped in ancient carbonaceous matter to put age constraints on potential paleo-fossils [5].

In this study, we show that 2.0 Ga-old bitumen samples from Franceville (Gabon) are extremely enriched in Xe. This confirms that C-rich materials are reservoirs of Xe allowing precise isotope studies. However, Xe released from these samples presents a mass-dependent isotopic fractionation >3.5‰/a.m.u in favor of heavy isotopes relative to light ones. Other noble gases do not show isotopic deviations from air. The presence of this mass-dependent isotopic fractionation is striking since it is of opposite sign compared to previous studies on ancient atmospheric Xe. The strong enrichment and the isotopic fractionation suggest that the initial atmospheric Xe signal has been altered. A potential explanation would be several episodes of filling-emptying of the pores present in the carbon structure [6]. Additional work is required to determine under which condition a carbon-rich lithology can be considered as a good proxy for paleo-atmospheres. [1] Ozima M. & Podosek F. (2002) *Noble Gas Geochemistry* [2] Pujol *et al.* (2009) *GCA* **73**, 6834-6846 [3] Avice *et al.* (2017) *Nat. Comm.* **8**, 15455 [4] Avice et al. (2018) *GCA* **232**, 82-100 [5] Zahnle et al. (2019) *GCA* **244**, 56-85 [5] Bekaert *et al.* (2018) *Sci. Adv.* **4**, eaar2091 [6] Torgersen *et al.* (2004) *EPSL* **226**, 477-489.