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The Composition of the Earth('s Noble Gases)

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Noble gases are present at trivial concentrations in the Earth's interior, and yet they provide valuable records of accretion and planet-scale differentiation processes. Primordial volatiles acquired and retained throughout the accretion process remain in the mantle today. Noble gas isotopes generated by nuclear reactions (such as radioactive decay) have been produced in the Earth's interior throughout its history. Significant gas exchange has occurred between the interior and surface reservoirs on billion-year timescales: volcanic outgassing has carried magmatic gases into the atmosphere, and subduction of altered oceanic plates has brought an influx of atmospheric gas into the interior. The elemental abundance patterns and isotopic compositions of mantle noble gases record all of these processes and provide detailed information about Earth's past.

Isotopes that are not produced by nuclear reactions are referred to as "primordial" in the noble gas literature. Ratios of primordial noble gas isotopes trace a simplified set of processes: volatile delivery during accretion, and the influx of atmospheric volatiles into the interior. Corrections for atmospheric contamination must be made to determine mantle source compositions, and ratios of radiogenic isotopes must be evaluated to determine whether magmatic degassing has significantly altered elemental ratios (*e.g.*, ratio of radiogenic ^{4}He to ^{40}Ar). In a small set of samples for which mantle source compositions have been determined and elemental ratios are minimally affected by fractionating processes, noble gas primordial isotopes are found to vary systematically.

The emerging picture is one where solar nebular gas was dissolved into a terrestrial magma ocean and retained through a giant impact stage. The trapped solar gas was mixed with gases carried by solid materials delivered throughout the accretion process. If even a small portion (<0.1% by mass) of the solid mass of the Earth was carbonaceous in nature, this would dominate the accreted budgets and isotopic compositions of Kr and Xe in the mixture of mantle noble gases due to the high concentration of Kr and Xe in carbonaceous materials compared to non-carbonaceous materials, and due to the strong contrast between solar and chondritic noble gas elemental abundance patterns [1].

[1] Parai (2022) *PNAS* 119 (29) e2201815119