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Atmospheric noble gas isotope and bulk K/U ratios as a constraint on the early evolution of Venus and Earth

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Abstract

While Venus and Earth were accumulating mass within the solar nebular these protoplanets also captured significant hydrogen dominated atmospheres by picking up gas from the circumstellar disk during the formation of the Solar System (e.g. [1]). These primordial atmospheres were then quickly lost by hydrodynamic escape after the disk dissipated. After a short but efficient boil-off phase the EUV-driven hydrodynamic flow of H-atoms dragged heavier elements with it at different rates, leading to changes in their isotopic and elemental ratios [2,3,4], which is reflected in the present-day atmospheric noble gas isotope and elemental ratios of Venus and Earth. Depending on the disk lifetime and the initial composition $^{36}Ar/^{38}Ar$, $^{20}Ne/^{22}Ne$ and bulk K/U ratios observed for both planets can be best explained if the Sun was born between a weakly and moderately active star and if Venus and Earth had grown to ~85-100% and ~53-58%, respectively, of their current masses by the time the nebula gas dissipated approximately 3.5 Myr after formation of the Sun. If proto-Earth accreted its mass from up to 40% carbonatious chondritic-like material [5] then the planet must have been grown to about 80% of its final mass as long as it was surrounded by the escaping primordial atmosphere (~7 Myr). Our results are therefore in agreement with a fast accretion of thermally processed disk material planetary embrios, with Hafnium-Tungsten chronometric fast accretion scenarios of the proto-Earth (e.g. [6]), and a noble gas origin based on a mixture of primitive meteoroids and a small remnant of the proto-solar nebula [7].

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