NOBLE GAS VARIATIONS IN UREILITES DEMONSTRATE HETEROGENOUS VOLATILE DISTRIBUTION IN THE EARLY SOLAR SYSTEM

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Introduction:

Inner Solar System bodies are depleted in volatile elements relative to primitive chondritic meteorites. The origin of volatiles on inner solar system planetary bodies is therefore considered to be the result of late deliveries of volatile-rich material from the outer solar system [1]. However, Earth and Mars record evidence of solar volatiles within their mantles [2,3,4] indicating that these planets were able to accrete volatiles early [5] during the existence of the protosolar nebula (4 Myr after CAI) [6]. The timing and origin of volatile element accretion to terrestrial planets therefore remains enigmatic.

Ureilites are a group of achondrites, originating from a single, inner solar system body [7]. Ureilites are essentially the remnants of the mantle that has undergone extensive melt extraction [8]. The ureilite planetary body (UPB) is considered to have accreted ~1.6 Myr after CAI formation representing one of the oldest terrestrial planetary body in the solar system [9]. Ureilites therefore provide a unique opportunity to probe the composition of volatiles within the solar system and the mechanisms through which planetary bodies acquire and preserve volatiles throughout their accretion.

Samples and Methods: Six North West African ureilites (NWA 2236, NWA 7686, NWA 8049, NWA 8172, NWA 11368, NWA 11032) were chosen for heavy noble gas analysis. The details of the samples used in this study have been presented previously [10,11]. All samples analysed are unbrecciated main group ureilites, which are known to have extremely uniform and well-equilibrated olivine core compositions, with limited to no intergrain or intragrain variability [12]. Olivine cores within the samples analysed as part of this study have Mg# ranging from 76.9 to 96.9. Samples were specifically chosen to span the range of compositions previously measured within ureilites (Mg# = 74 - 97) [7]. Noble gases were extracted from bulk samples weighing between 6 and 32 mg. Noble gases were released at several temperatures using a tungsten filament furnace with Ar, Kr and Xe isotopes being measured.

Results and Discussion: Concentrations of ^{36}Ar, ^{84}Kr and ^{132}Xe are shown to be correlated with the Mg# of the olivine cores, with samples containing high Mg# olivines being enriched in noble gases relative to low Mg# number samples. The majority of ^{36}Ar/^{132}Xe and ^{84}Kr/^{132}Xe values fall intermediate between chondritic phase Q and solar. Krypton and xenon isotopes are similar to phase Q [13], however significant variations exist across the samples, with the Kr and Xe isotopic signatures lying along a mixing line between solar and the presolar HL component [14]. Interestingly, Xe isotopes also appear correlated with Mg#, with samples having the highest Mg# being more enriched in the heavy Xe-HL than low Mg# samples.

The correlation between noble gas elemental abundances and isotopic ratios suggests that that silicate fractions and noble gas bearing carbon phases may share a common origin. Previously, the similar highly-fractionated noble gas elemental and isotopic ratios in ureilites and phase Q, relative to solar, suggested they may have acquired noble gases through a similar nebular process [15]. However, it is not readily apparent why noble gas elemental abundances and isotopic ratios should be correlated with the Mg# of olivines. We therefore suggest that range of noble gas compositions in ureilites can be best accounted for by incomplete mixing between two distinct components, one being inherited directly from chondritic-like precursors (phase Q), and the other being derived from solar-like component potentially implanted from the solar wind.

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