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Planetary formation and evolution through the lens of zinc and copper isotopes

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The accurate and precise analysis of the isotopic composition of first-row transition metals in both meteoritic and terrestrial materials has afforded significant insights into the formation and evolution of rocky bodies of the inner solar system. Here we specifically focus on two of these isotope systems, zinc and copper.

Zinc isotopes have played a crucial role in understanding the delivery and redistribution of (moderately) volatile elements in the inner solar system. Pioneering studies comparing chondrites to Earth indicate that Earth's relative volatile depletion is unlikely to be a result of evaporative volatile loss [1,2]. Additionally, heavy Zn isotope enrichments in both lunar rocks and some achondrites compared to the Earth and chondrites suggest that impact-related evaporation-driven loss of volatile material was a key process in both our Moon's and other bodies' formation [3,4]. Moreover, the discovery of nucleosynthetic Zn isotope anomalies in primitive meteorites has placed robust estimates on the amount of volatile material delivered to Earth from the outer solar system [5-7]. Investigation of Zn isotope anomalies in meteorites is still in its early stages and promises to reveal further important findings.

Copper's siderophile and chalcophile nature has allowed it to be applied to better understand the physiochemical conditions of planetary differentiation in the inner solar system. A copper isotope offset between Earth's mantle and a chondritic bulk Earth [8,9] has been used to imply that a significant amount of sulphur partitioned into Earth's core during differentiation [9]. Whilst this conclusion is not uncontroversial, new achondrite data presented here indicates that Cu isotope fractionation via sulphide fractionation also took place elsewhere in the solar system. However, there is still much work to be done to better apply Cu isotopes to understanding planetary processes.

[1] Luck et al., 2005, GCA 69; [2] Albarède 2009, Nature 461; [3] Paniello et al., 2012, Nature 490; [4] Moynier et al, 2011, GCA 75; [5] Savage et al., 2022 Icarus 386; [6] Steller et al., 2022 Icarus 386; [7] Martins et al., 2023, Science 379; [8] Luck et al., 2003 GCA 67 [9] Savage et al, 2015 GPL 1