

TIN STABLE ISOTOPE VARIATIONS IN CHONDRITES: IMPLICATIONS FOR PLANETARY AND NEBULAR PROCESSES

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Introduction: The abundance and isotope composition of volatile elements can provide valuable insight into planet formation processes, that involve condensation and evaporative loss of elements from the initial formation of dust in the solar nebula to planetesimal accretion. During these processes isotopes of volatile elements can undergo mass dependent fractionation, which therefore can be used as proxies to understand the physical and chemical processes leading to their fractionation. Information on these processes is preserved in meteorites and other planetary materials. The volatile element Sn is particularly suitable for such investigations. Tin has ten stable isotopes which are formed by r-, s- and p- processes in stars. Additionally, due to its moderately volatile nature (50% condensation temperature of 704 K) [1], Sn shows a strong depletion (>90% depleted relative to volatiles) in most planetary materials. Apart from being a heavy volatile element, Sn also behaves geochemically as a chalcophile/siderophile element. Hence, Sn could be a useful candidate to understand the origin of volatiles in rocky planets, the nature of the materials incorporated at different planetary accretion stages, and also to acquire information on the planetary core formation.

Methodology: A novel wet chemistry based method was designed at the Institut für Geologie, Universität Bern to determine the mass dependent isotope fractionation of Sn in various chondritic meteorites and terrestrial rocks. The technique was developed considering the following points: 1) The strong tendency of Sn to react with mineral acids during sample processing leading to potential secondary laboratory-induced isotopic fractionation caused due to volatile loss. 2) To be able to precisely measure small quantities of Sn (~20-100 ng), as most planetary materials are highly depleted in Sn relative to other similarly volatile elements. 3) Develop a double spike based analysis protocol to obtain high precision measurement that can distinguish even small isotope variations of Sn in meteorites relative to terrestrial rocks. For our studies, 14 terrestrial rock reference standards and 37 bulk chondritic meteorites together with their matrix and chondrule separates were carefully processed in various table-top hotplate based acid dissolution methods. Sn was isolated from several isobarically interfering as well as major matrix elements using a two-stage column chromatography. Prior to sample dissolution, all samples were mixed with a ¹¹⁷Sn-¹²²Sn double spike to monitor any secondary mass bias introduced during sample processing or subsequent MC-ICP-MS analysis [2].

Results and Discussion: Repeated analysis of NIST SRM 3161a in various sessions and several USGS reference materials yielded a long term external repeatability of 0.021 ‰ (2s.d.) for $\delta^{122/118}\text{Sn}_{\text{NIST SRM 3161a}}$. The range in variations of $\delta^{122}\text{Sn}$ (i.e. difference between most and least fractionated sample) is observed to be largest in bulk ordinary chondrites (1.3 ‰; n = 12), while that range is least in enstatite chondrites (0.24 ‰; n = 9) and with carbonaceous chondrites showing an intermediate range (0.54 ‰; n = 15). The ordinary chondrites are the most depleted (0.33 ± 0.13), while carbonaceous chondrites shows an intermediate (0.77 ± 0.59) and enstatite chondrites the least depleted (1.77 ± 0.59) in Sn (Mean \pm 2s.d. in $\mu\text{g/g}$). The $\delta^{122}\text{Sn}$ of bulk ordinary, enstatite and carbonaceous chondrites overlaps with a presently estimated bulk silicate Earth (BSE) $\delta^{122}\text{Sn}$ composition ($\delta^{122}\text{Sn} = 0.49 \pm 0.11$ ‰ 2s.d.) [3]. However, the bulk ordinary chondrites shows a large scatter. This observed scatter falls within the range presented in recently published data ($\delta^{122}\text{Sn} = -1.08$ to 0.543 ‰, $\delta^{124/118}\text{Sn} = -2.02$ to 0.64 ‰) [4, 5]. Such apparently randomly scattering Sn isotope variations could be a result of metamorphism or impact induced heating as observed in tektites [4, 6]. The $\delta^{122}\text{Sn}$ of the carbonaceous group shows a systematic variation with their respective $[\text{Sn}]^{-1}$ which is similar to other moderately volatile elements viz. Te [7], indicating the presence of a volatility trend during condensation in the solar nebula. Pooled chondrules separated from Allende show a $\delta^{122}\text{Sn}$ that is very distinct from the associated matrix. The measured $[\text{Sn}]$ in these Allende chondrules also fits within 95% c.i. of an estimated Sn abundance in the non-matrix components determined based on the correlation between $[\text{Sn}]$ and matrix mass fraction of CI, C2-ung, CV, CM, CO, and CR chondrites in this study as well as others [7].

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