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Hiroshima spherules as an analog of early solar system condensates

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Glass spherules produced during the Hiroshima nuclear explosion were recently discovered by [1]. The 3 isotopes of Si and O were measured for comparison with early solar system condensates (i.e. Ca-,Al-rich refractory inclusions, CAIs). Because the conditions of formations of these spherules cannot be reproduced in the laboratory, their analyses bring new constraints on the conditions under which mass-dependent (MDF) and mass-independent isotopic fractionation (MIF) processes take place.

The triple silicon isotopic compositions of the Hiroshima glasses show large MDF (from -23.0±0.9‰ to -1.5±0.5‰ for δ^{30}Si) demonstrating substantial kinetic isotopic fractionation during condensation of the spherules. These fractionations are consistent with the modeling of Si isotopic variations during a rapid (3.7 sec) condensation sequence (from 4000 to 1000K) in a gas having the chemical composition of the vaporized Hiroshima city materials. The triple O isotopes also show a large range of variations (from 0.4±0.5‰ to 24.0±0.2‰ for δ^{18}O) with significant positive and negative departures from MDF (-3.1±0.6≤ Δ^{17}O ≤ 1.1±0.8 ‰) in ≈ 40% of the data.

The fact (i) that the composition of the Hiroshima glasses (i.e. melilitic, anorthositic) is close to that of CAIs, (ii) that the range of Si variations is similar to that observed in CAIs and attributed to evaporation/condensation processes [2, 3] and (iii) that the Hiroshima glasses show a signature of MIFs in oxygen isotopes, demonstrate that they are condensates from the nuclear plasma. The major differences with the solar nebula in terms of pressure (1 bar for Hiroshima versus 10^{-4} bar for the nebula) and chemical composition (dioxygen and water mixed with anthropic material versus chondritic) may account for the differences with meteoritic condensates.

[1]. Wannier, M. M. A., et al. (2019). *Anthropocene*, *25*, 1–10. https ://doi.org/ 10.1016/j.ancene. 2019. 100196. [2] Clayton, R. N., Hinton, R. W., & Davis, A. M. (1988). *Philosophical Transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences*, *325*(1587), 483–501. https ://doi.org/10.1098/rsta.1988.0062 [3] Marrocchi, Y., Villeneuve, J., Jacquet, E., Piralla, M., & Chaussidon, M. (2019). Rapid condensation of the first Solar System solids. *Proceedings of the National Academy of Sciences*, *116*(47), 23461-23466.