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Tracing the Origins of the Ice Giants through Noble Gas Isotopic Composition

Kathleen Mandt[1], Olivier Mousis[2], Jonathan Lunine[3], Bernard Marty[4], Thomas Smith[5], Adrienn Luspay-Kuti[1], and Artem Aguichine[2]

[1]JHU Applied Physics Laboratory, Laurel, United States of America (kathleen.mandt@jhuapl.edu)
[2]Aix Marseille Université, CNRS, CNES, LAM (Laboratoire d'Astrophysique de Marseille), Marseille, France
[3]Department of Astronomy and Carl Sagan Institute, Cornell University, Ithaca NY 14853, USA
[4]Centre de Recherches Pétrographiques et Géochimiques, UMR 7358, CNRS & Université de Lorraine, Vandoeuvre-lès-Nancy, France
[5]Chinese Academy of Sciences, Beijing, China

The current composition of giant planet atmospheres provides information on how such planets formed, and on the origin of the solid building blocks that contributed to their formation. Noble gas abundances and their isotope ratios are among the most valuable pieces of evidence for tracing the origin of the materials from which the giant planets formed. In this review we first outline the current state of knowledge for heavy element abundances in the giant planets and explain what is currently understood about the reservoirs of icy building blocks that could have contributed to the formation of the Ice Giants. We then outline how noble gas isotope ratios have provided details on the original sources of noble gases in various materials throughout the solar system. We follow this with a discussion on how noble gases are trapped in ice and rock that later became the building blocks for the giant planets and how the heavy element abundances could have been locally enriched in the protosolar nebula. We then provide a review of the current state of knowledge of noble gas abundances and isotope ratios in various solar system reservoirs, and discuss measurements needed to understand the origin of the ice giants. Finally, we outline how formation and interior evolution will influence the noble gas abundances and isotope ratios observed in the ice giants today. Measurements that a future atmospheric probe will need to make include (1) the $^{3}He/^{4}He$ isotope ratio to help constrain the protosolar D/H and $^{3}He/^{4}He$; (2) the $^{20}Ne/^{22}Ne$ and $^{21}Ne/^{22}Ne$ to separate primordial noble gas reservoirs similar to the approach used in studying meteorites; (3) the Kr/Ar and Xe/Ar to determine if the building blocks were Jupiter-like or similar to 67P/C-G and Chondrites; (4) the krypton isotope ratios for the first giant planet observations of these isotopes; and (5) the xenon isotopes for comparison with the wide range of values represented by solar system reservoirs.

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