

The ortho-to-para ratio of gaseous water molecules desorbed from ice made from para-water

*Tetsuya Hama¹, Akira Kouchi¹, Naoki Watanabe¹

1. Institute of Low Temperature Science, Hokkaido University

Water has two nuclear-spin isomers: ortho- and para-H₂O. Some observations of interstellar space and cometary comae have reported the existence of gaseous H₂O molecules with anomalous ortho-to-para ratios (OPRs) less than the statistical value of three. This has been often used to estimate the formation temperature of ice on dust, which is inferred to be below 50 K. The use of the OPR as a temperature probe requires the assumption that the OPR of H₂O desorbed from ice is related to the ice-formation temperature. However, the mechanism that determines the OPR of H₂O desorbed from ice is unclear, and we still do not understand the origin of the anomalous OPRs measured for interstellar H₂O. An important limiting factor is the lack of a laboratory study that defines the initial nuclear-spin state of H₂O for the formation of ice at low temperatures.

The present study measures the OPR of H₂O desorbed from ice made from para-H₂O monomers at 11 K. The para-enrichment of H₂O monomers is achieved in a solid Ne matrix (H₂O/Ne = 1/1000) at 6 K. The Ne matrix is then warmed to 11 K to sublime Ne only, resulting in the formation of ice by the aggregation of para-H₂O monomers. We perform direct measurements of the OPR of H₂O desorbed from ice using rotationally resolved, resonance-enhanced multiphoton ionization spectroscopy. The photodesorbed H₂O molecules from the ice have the statistical OPR value of three, demonstrating the immediate nuclear-spin state mixing of H₂O towards the statistical value of ice even at 11 K. The OPR of H₂O thermally desorbed from the ice also shows the expected statistical value. Our results indicate that the OPR of H₂O desorbed from interstellar ice should be the statistical value regardless of the formation process of the ice, which cannot be used to deduce the ice-formation temperature. This study highlights the importance of interstellar gas-phase processes in understanding anomalous abundance ratios of nuclear-spin isomers of molecules in space.

Hama, T., Kouchi, A., & Watanabe, N. 2016, *Science*, 351, 65.

Keywords: water ice, ortho-to-para ratio, nuclear spin isomer, comet, interstellar molecular cloud