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彗星コマの水分子の核スピン温度は彗星氷の生成温度を反映しているか？
Does nuclear-spin temperature of water molecules in comet coma reflect the formation temperature of the cometary ice?

羽馬 哲也 [1*], 渡部 直樹 [1], 香内 晃 [1]
HAMA, Tetsuya[1*], WATANABE, Naoki[1], KOUCHI, Akira[1]

[1] 北海道大学　低温科学研究所
[1]Institute of Low Temperature Science, Hokkaido University

The nuclear-spin temperature (T_{spin}) is derived from the ortho-to-para ratio (OPR) of molecules such as H_2 or H_2O, which contains two protons with spin of 1/2; thus, its total spin state can be either 0 (singlet, para) or 1 (triplet, ortho). In the case of H_2O, the OPR is equal to 3 in statistical equilibrium, which is achieved at temperatures above ˜50 K.

T_{spin} of interstellar H_2O molecules has been observed, because they are suggested to be indicators of these molecules' physical and chemical histories. In cometary coma, T_{spin} of H_2O has been derived to be typically ˜30 K. Recently, it was found that there has been a wide range of the observed values of T_{spin} of H_2O from 13.5 K to ˜50 K in interstellar space.

Since nuclear-spin conversion is unlikely to occur for isolated molecules in the gas phase. These values have been implicated as the temperature of cold grains at molecular condensation or formation in a molecular cloud, or in the solar nebula, for example. However, the real meaning of the observed T_{spin} remains a topic of continuing debate. For a proper interpretation of T_{spin} of molecules observed in interstellar space or cometary coma, the correlation between T_{spin} and temperatures of ice at condensation, formation, and desorption needs to be investigated. Even T_{spin} of thermally desorbed H_2O from water ice condensed or formed at low temperature is yet to be experimentally measured.

The present study measured the T_{spin} of H_2O thermally desorbed from pure amorphous solid water (ASW) deposited at 8 K by employing a combination of temperature programmed desorption and resonance-enhanced multiphoton ionization (REMPI) methods. We also produced ASW at 8 K by photolysis of a CH_4/O_2 mixture (photoproduced ASW) for the idea that T_{spin} of H_2O molecules formed at a low temperature relates to the formation environment.

As a result, thermally desorbed H_2O molecules at 150 K from all ice samples prepared at 8 K showed T_{spin} almost at the statistical high-temperature limit (>˜30 K). T_{spin} of desorbed H_2O from vapor-deposited pure ASW is almost at the statistical high-temperature limit (>˜30 K), while its value was almost the same after leaving it for 9 days at 8 K. These results suggest that the T_{spin} of gaseous H_2O molecules thermally desorbed from ice does not necessarily reflect the surface temperature at which H_2O molecules condensed or formed. We discuss the possibility of nuclear-spin conversion of H_2O in water ice.

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