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# New insight into $\mu$SR in water

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Over the past four decades, muon spin rotation and relaxation technique in water and ice has been reported by several groups [1-4]. Most of the previous studies were focused on muonium chemistry (detection, its relaxation, reaction and frequencies) in water and ice. To deepen the understanding of muon behavior in water and application of $\mu$SR to life sciences and hydrated samples, we performed temperature dependent $\mu$SR study in water. We found the temperature dependent oscillation in zero-field spectra in ice for the first time and proposed a new model – interaction between four spin-one-half system – to interpret the data. We found two stopping sites (proportion of 35% and 10% of incident muons) for muons in hexagonal ice in which the muons in larger fraction (35%) move towards optimized geometry site with temperature approaching the melting point. The distances of the muon and protons are successfully detected in subatomic scale. This study will be helpful to understand the charge dynamics in materials, for example, ion diffusion in battery materials, proton transfer in hydrated materials, proton transfer in biological membranes and in general transport of other spin-nuclei in solid state materials.

[1] P. W. Percival, et al., *Chem. Phys. Lett.* **39** (1976) 333; *Hyperfine Interact.* **8** (1981) 325; *Hyperfine Interact.* **18** (1984) 543; *Chem. Phys.* **32** (1978) 353; *Chem. Phys.* **95** (1985) 321.
[2] K. Nagamine, et al., *Chem. Phys. Lett.* **87** (1982) 186.
[3] S. Cox, et al., *Hyperfine Interact.* **65** (1991) 993; *Physica Scripta* **1992** (1992) 292; *Hyperfine Interact.* **86** (1994) 747.
[4] Y. Wang, et al., *Physica B: Condensed Matter* **350** (2004) E451.

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