Oxygen dependent muonium relaxation in liquid and frozen water

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Muons injected into water form a diamagnetic muon and a paramagnetic isotropic muonium species in addition to a missing fraction. However, in frozen water, we found two diamagnetic muon species and an anisotropic muonium. The paramagnetic muonium executes spin-exchange interaction and/or chemical reaction with paramagnetic molecular oxygen exist in the water [1,2]. The detection of oxygen helps to develop a noninvasive muon method for detection of hypoxia (low oxygen concentration) in tumor/cancer tissues.

We found the relaxation of muonium in liquid water before freeze is higher than that in liquid water after freeze-thaw measured in the weak transverse field (TF) measurement (Fig.1). In the frozen water, we observed the Mu signal at zero-field and weak TF as well. The relaxation of Mu is higher in normal water than that in N_2 saturated water.

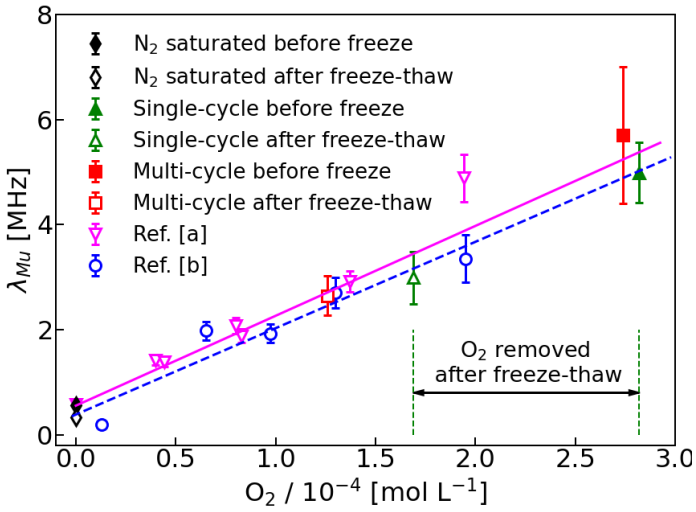

Fig. 1 Relaxation rate of Mu (λ_{Mu}) with concentration of molecular oxygen in liquid water. The λ_{Mu} in water before freeze found higher than that in the water after freeze/melt. (Ref. [a] and [b] are [1] and [2], respectively).

References

[1] E. Roduner, et al., *J. Chem. Soc., Faraday Trans.* **91**, (1995) 1935–1940.

[2] A. D. Pant, et. al., *Nucl. Instrum. Methods Phys. Res*. A **1011,** 165561 (2021).