Spin relaxation of polarized Xe atoms at the liquid-solid interface

Takako Yamamoto, Kiyoshi Ishikawa, and Yoshihiro Takagi

Graduate School of Material Science, University of Hyogo, Hyogo 678-1297, Japan

We study the spin relaxation of hyperpolarized ^{129}Xe atoms at the interface between liquid and solid. The polarization of Xe atoms decays in bulk solvents mainly due to the magnetic dipole interaction with the nuclei in solution. Since the moving magnetic dipoles interact transiently with each other, the lower viscosity leads to the smaller decay rate at the fast motion limit. On the other hand, the wall relaxation can be dominant in the low-viscosity solution because Xe atoms collide with the cell walls within the relaxation time of bulk solution. Therefore, the minimal value typically appears in the temperature dependence of decay rate. If we succeed in suppressing the wall relaxation, the resonance signals will be detected many times without the replacement for depolarized atoms. In addition, we can find the weak perturbations hidden under the veil of both relaxations in the finite size of cell. The spin relaxation at the gas-solid surface has been reported as to the cross-relaxation of ^{129}Xe nuclei with the protons of coating material [1] and the relaxation of ^{3}He nuclei due to the magnetic sites [2]. The wall relaxations in solutions are, however, not fully understood.

We measured the decay rate of spin polarization of Xe atoms dissolved in the deuterated ethanol (ethanol-d_6). The walls of glass cell were coated with the deuterated paraffin (eicosane-d_{42}). The use of deuterated materials is essential to investigating the surface interaction. The Xe atoms were polarized by the spin-exchange optical pumping with a flow-type Xe polarizer [3]. The polarization was approximately 4 %, and total pressure of mixed gas (^{4}He, N_2, and natural abundant Xe) was 290 kPa. The decay rate of Xe gas is less than that of the dissolved atoms. The polarizations of Xe atoms in liquid and gas phases are subject to the wall relaxations with the different time constants. This situation induces the complex decay phenomena if Xe atoms pass freely over the gas-liquid boundary. We used the glass cell designed to minimize the exchange rate of Xe atoms between both phases [4]. The translational motion of Xe atoms and ethanol molecules was of the convection rather than the diffusion at the time scale longer than 0.1 s. It was confirmed by the steady-gradient spin-echo diffusiometry. Therefore, Xe atoms collides many times with the walls within the relaxation time. Figure 1 shows the temperature dependence of decay rate and its change by the coating. The decay rate around 240 K is significantly smaller in the coated cell than in the uncoated cell. Taking account of the dependence of decay rate on the field strength and the surface area of coating as well as the temperature, the suppression of spin relaxation was found to be because the characteristic time of relative motion between deuterons and Xe nuclei at the interface is different from in the solution.

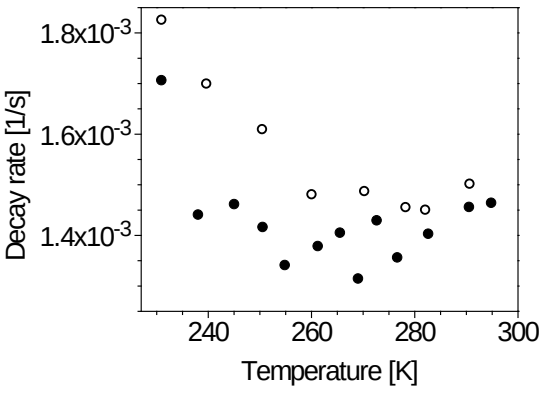

Fig. 1 The decay rate of Xe polarization dissolved in ethanol-d_6 for the coated (solid circle) and uncoated (open circle) cell at 0.33 T.

[1] Driehuys B., Cates G., and Happer W., Phys. Rev. Lett. **74**, 4943 (1995).
[2] Jacob R., Morgan S., and Saam B., Phys. Rev. Lett. **87** 143004 (2001).
[3] Ishikawa K., Imai H., and Takagi Y., J. Chem. Phys. **120**, 7602 (2004).
[4] Ishikawa K., Imai H., and Takagi Y., Phys. Rev. A **70**, 042712 (2004).