Measurement of ^{41}S spin polarization

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Spectroscopic data have indicated the erosion of the $N = 28$ shell gap in several studies[1–4]. In particular, the isomeric state of ^{43}S at 320 keV is suggested to have a quasi-spherical shape with a spin-parity of $7/2^{-}$[5,6]. On the other hand, the spin-parity of the ground state of ^{43}S has been neither confirmed nor predicted uniquely[5,7,8]. In order to investigate the mechanism of the $N = 28$ magicity loss through the determination of the spin parity of the ground state of ^{43}S, we aim to measure systematically the ground state electromagnetic moments for ^{41,43}S.

The electromagnetic moments of nuclei in their ground states are measured by combining the technique to produce spin-polarized RI beams[9] and the method of β-ray-detected nuclear magnetic resonance (β-NMR). In this scheme, the RIs are stopped in a crystal, which provides spin-lattice relaxation times T_1 that are longer than the β-decay halflife of the RI. In order to find out optimum conditions for the β-NMR measurement, the T_1 measurements were carried out for stopper crystal candidates, such as Si, ZnS, and CaS. In the measurements, an RI beam of ^{41}S, for which a large yield was expected, was used, instead of ^{43}S, to measure the relaxation time T_1.

The experiment was carried out at the RIPS[11] facility at RIBF. The RI beam of ^{41}S was produced by the fragmentation of ^{48}Ca projectiles at an energy of $E = 63$ MeV/nucleon on a 0.52 mm-thick ^{9}Be target. The intensity of the ^{48}Ca beam at the target was typically 200 pnA. The isotope separation of the ^{41}S beam was conducted by the RIPS beam line, in which the emission angle θ_{F} and momentum p_{F} of the fragment were selected so as to realize ^{41}S spin-polarization. Under the condition of $p_{\mathrm{F}} = p_0 \times (1.015 \pm 0.025)$ and $\theta_{\mathrm{F}} > 1^{\circ}$, where p_0 represents the central momentum of the fragment ^{41}S, the ^{41}S beam was obtained from RIPS with a purity of 47% and an intensity of 1.6×10^4 particles/s.

The ^{41}S beam was then transported to the final focal plane and implanted into a stopper crystal located at the center of the adiabatic field rotation (AFR) device[12]. The AFR device enables us to extract the asymmetry of β-ray emission without relying on the NMR technique, by only rotating a pair of Nd permanent magnets adiabatically. The β rays emitted from ^{41}S were counted by plastic scintillators, two of which were set above the crystal and two others were set below it. The measurement was conducted according to the following sequence of cycles: beam irradiation for 2,900 ms, rotation of the AFR magnets for 150 ms, waiting time of 200 ms, and the β ray counting for 2,900 ms. The irradiation and counting time periods were chosen to be comparable with the meanlife of ^{41}S. The waiting margin was inserted in order to avoid spurious effects that might arise from a tiny vibration of the magnets following the rotation. The value of AP was deduced from β rays counts obtained in the following four different configurations with the field directions up/down and the magnet rotation true/false (hence, the spin is flipped/not flipped). Here, A and P denote the asymmetry parameter for the β-ray emission and the degree of polarization of ^{41}S, respectively. From the results of the AFR measurement, we obtained $AP = -0.14(4)\%$ with the CaS multi-crystal stopper of 0.5 mm thickness, and T_1 was found to be longer than 4,600 ms in 1σ confidence level.

Following the T_1 and AP measurements, the g-factor search by means of the β-NMR method was carried out using the spin-polarized ^{41}S with $AP = -0.14\%$ and the CaS crystal. Because the range within which the g-factor of ^{41}S is predicted theoretically is quite wide, a fast switching system for changing the tank-circuit frequency[13] has been used. The results of the NMR measurement are under analysis.

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