Shape coexistence in the N=19 neutron-rich nucleus ^{31}Mg explored by β-γ spectroscopy of spin-polarized ^{31}Na[†]

H. Nishibata,[*1,*2] T. Shimoda,[*1] A. Odahara,[*1] S. Morimoto,[*1] S. Kanaya,[*1] A. Yagi,[*1] H. Kanaoka,[*1] M. R. Pearson,[*3] C. D. P. Levy,[*3] and M. Kimura[*4]

One of the highlights of the recent nuclear physics is the shape coexistence of nuclei located far from the β-stability line. In particular, neutron-rich nuclei with neutron numbers close to the neutron magic number N = 20, so-called the "island of inversion"[1)], have been intensively studied. However, the structures are still not clear because there exists few information on excited states, such as spin-parity, for most of the island-of-inversion nuclei.

We study the neutron-rich nucleus ^{31}Mg which is located around the "island of inversion" region. The level structure of odd-mass ^{31}Mg is one of the most sensitive probes of shape coexistence because the last neutron orbit, which governs the spin-parity of the level, is strongly affected by the nuclear structure. In the present work, detailed data are presented for the excited states of ^{31}Mg, obtained through a unique and extremely promising method[2)] to measure spin-parity based on the β-decay spectroscopy of spin-polarized ^{31}Na.

Our method uses an asymmetric β decay of the polarized nucleus in the allowed transition. The angular distribution is expressed as $W(\theta) \simeq 1 + AP\cos\theta$, where A, P, and θ are the asymmetry parameter for each β transition, the spin polarization, and the emission angle of the β rays with respect to the polarization direction, respectively. The essential point is that the asymmetry parameter takes three different values depending on the spins of the parent and daughter states. In the case of the β decay of ^{31}Na ($I^\pi = 3/2^+$), the asymmetry parameter is either -1.0, -0.4, or $+0.6$ for the possible daughter state with a spin-parity of $1/2^+$, $3/2^+$, or $5/2^+$, respectively. Therefore, from the experimental asymmetry value, the spin-parity can be unambiguously assigned. Further information on this method can be found in Ref.[2)]

The experiment was performed at the Isotope Separator and Accelerator (ISAC) facility in TRIUMF, where a highly polarized Na beam was achieved by simultaneously pumping both atomic ground-state levels with two laser frequencies. The β-rays and γ-rays associated with ^{31}Na β decay were measured at the end of the Osaka beam line (for detailed information on the experimental setup, see the original Letter[†]).

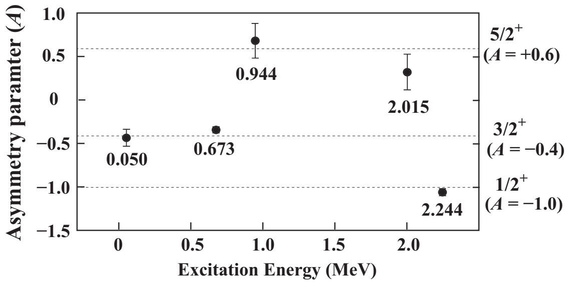

Fig. 1. Experimental asymmetry parameters for the levels at 0.050, 0.673, 0.944, 2.015, and 2.244 MeV.

Figure 1 shows the experimental asymmetry parameters. It is clearly seen that the experimental values are consistent with one of the expected values. Hence the spins and parities are firmly assigned as $1/2^+$ for the 2.244-MeV level, $3/2^+$ for the 0.050- and 0.673-MeV levels, and $5/2^+$ for the 0.944- and 2.015-MeV levels. The spins of negative-parity levels are also limited based on transition intensities from the levels with spin-parity assigned in the present work. Furthermore, 11 γ rays and 2 levels are newly found by analyzing the γ-γ coincidence data.

From the obtained spins and energies of the levels in ^{31}Mg, we propose that the positive-parity levels [$1/2^+$ 0 MeV, $3/2^+$ 0.050, $5/2^+$ 0.944, ($7/2^+$) 1.155] and negative-parity levels [($3/2^-$) 0.221, ($7/2^-$) 0.461, ($1/2^-$) 1.029, ($11/2^-$) 1.390] are members of the $K^\pi = 1/2^+$ and $1/2^-$ rotational bands, respectively. Through a level-by-level comparison between the experimental results and theoretical calculations of the AMD+GCM,[3)] it is found that the levels at 0.673 [$3/2^+$] and 2.015 MeV [$5/2^+$] show good correspondence with spherical levels predicted at 0.81 and 1.85 MeV. Furthermore, the experimental level at 0.942 MeV [($1/2^-$ or $3/2^-$)] is probably the $3/2^-$ level of the band-head of $K^\pi = 3/2^-$ rotational bands in the AMD+GCM calculations. However, the 2.244-MeV $1/2^+$ level cannot be explained by any theories at present. These results show clear evidence for shape coexistence in a low excitation energy region of ^{31}Mg.

References

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*1 Department of Physics, Osaka University, Osaka 560-0043, Japan
*2 RIKEN, Wako, Saitama 351-0198, Japan
*3 TRIUMF, 4004 Wesbrook Mall, Vancouver, BC V6T 2A3, Canada
*4 Department of Physics, Hokkaido University, Sapporo 060-0810, Japan