SHORT REPORT
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Possible magnetic rotational band in ^{77}Kr

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ABSTRACT: High-spin states of ^{77}Kr are studied via the fusion-evaporation reaction ^{68}Zn(^{16}O, 2p5n)^{77}Kr with the beam energy of 80 MeV provided by the Tandem accelerator at Japan Atomic Energy Agency (JAEA). The intensity of the beam is $I \sim 1$ pnA. In the present work, some new γ transitions are found to constitute the new band of the proposed level scheme. It is very similar to the M1 transition from the level energy, so it is proposed that this band is the M1 band.

KEYWORDS: in-beam γ-spectroscopy, magnetic dipole band, γ-γ coincidence measurement

INTRODUCTION

The mass A∼80 region shows a strong competition between single-particle excitation and collective rotation which has attracted so much attention in recent years [1]. In this region, the change in the nucleon number will greatly impact the nuclear structure. Therefore, its study will provide very rich information for nuclear structure research and become a powerful basis for testing various nuclear structure models. In the past years, researchers proved that there are magnetic rotation bands in those near-spherical nuclei [2] such as Pb isotopes which lie near the region of A∼190, around the A∼140 mass region, and in the nuclei near the region of A∼110. However, there are quite a few data in mass region A∼80 [3] e.g., in ^{82}Rb [4], ^{84}Rb [5–8], and its isotone ^{86}Y [9]. Besides magnetic rotation, there are some hot topics in this mass region such as signature inversion [10], chirality, and octupole correlation [11]. Existing research results indicate that in this region nuclei with a neutron number of less than 44 possess strong collective rotations while those with a neutron number of more than 47 show single-particle excitations. Our present experimental research object focuses on ^{77}Kr, which has 41 neutrons; hence, its structure is mainly characterized by the collective rotation. The discovery of an M1 band in the neighboring isotope ^{79}Kr [12] raised the question of whether a similar M1-dominated structure could be found in ^{77}Kr. So, finding the magnetic rotation band of ^{77}Kr is also one of the goals of our experiment.

Up to now, in the proton-deficient nucleus ^{77}Kr, high-spin states have been studied via the reaction ^{48}Ti(^{32}S, 2pn)^{77}Kr [13] with a 106 MeV ^{32}S beam from the Florida State University Tandem-LINAC accelerator. New levels at 9913 keV $41^+/2$ and 11760 keV $45^+/2$ have been identified. The negative-parity band was extended to a probable spin state of $(27^-/2)$ at an excitation energy of 5619 keV with 3 new levels identified. Spins were assigned or confirmed based on directional correlation ratios. The mean lifetimes of 21 states were measured using the Doppler-shift attenuation method. Later, the high-spin states of ^{77}Kr were identified via analysis of prompt γ-γ coincidences in the ^{58}Ni(^{29}Si, 2α2p) reaction [14] at 128 MeV at the Gammasphere facility. The evaporation channel selection was achieved using the Microball 4π detector array consisting of 95 CsI(Tl) scintillators. The $\alpha = -\frac{1}{2}$ band was extended to $39^+/2$, and the negative-parity signature pair was extended to $31^-/2$ at 6670 keV and $37^-/2$ at 8969 keV. Two new high-lying negative-parity bands were found extending from a state of spin $I =$

15/2 and energy 2604 keV to 17354 keV at $I = (55/2)$. Their measurements of the γ-γ directional correlation of oriented nuclei (DCO) intensity ratios have provided firm spin assignments up to spins of $45^+/2$, $37^-/2$ (in the old negative-parity structure), and $47^-/2$ (in the newly discovered bands). Our purpose of the present study is to populate more side bands, especially magnetic rotational bands with lighter projectiles and study their structural features.

EXPERIMENTAL DETAILS

High-spin states in ^{77}Kr are populated via fusion-evaporation reaction ^{68}Zn(^{16}O, 2p5n)^{77}Kr with the beam energy of 80 MeV (the intensity of the beam is $I \sim 1$ pnA) provided by the Tandem accelerator at Japan Atomic Energy Agency (JAEA), and the beam energy is chosen based on cross-section calculations and excitation function measurements. In this experiment, high-spin states in ^{80}Rb are also populated via the reaction ^{68}Zn(^{16}O, 1p3n)^{80}Rb, and the detail of results about this nucleus was published [1]. The γ-γ coincidence is measured by a detector array consisting of 12 Compton-suppressed HPGe-BGO detectors at JAEA. These detectors are placed at ±30°, ±60°, and ±90° relative to the beam direction. Each detector has an efficiency ranging from 40% to 60% and an energy resolution of about 2 keV for 1332.5 keV γ-ray. The detector's energy and relative efficiency calibrations are performed using standard sources such as ^{133}Ba and ^{152}Eu mounted at the target position. In this experiment, the isotopically enriched ^{68}Zn targets are self-supporting thin targets, which are rolled into a thickness of 0.57 mg/cm^2. The targets consist of a stack of 2 foils, which can increase the yield as well as avoid the deterioration of γ-ray energy resolution caused by the Doppler effect in the thick target. Events are collected in an event-by-event mode, when at least 2 Compton-suppressed HPGe-BGO detectors fire in coincidence. A total of 3.0×10^8 double- or higher-fold coincidence events are accumulated in this experiment.

RESULTS AND DISCUSSION

In the present work, some new γ transitions are found, which can make up a new band of the proposed level scheme shown as band 3 in Fig. 1. This band is connected by 3 γ transitions of 995 keV, 1285 keV, and 878 keV to the positive-parity $15^+/2$ state and negative-parity $15^-/2$ state, respectively. The energies of γ transitions within this band are 286–317–332–427–517 keV successively. Because the γ-γ directional correlation of oriented nuclei (DCO) intensity ratios are not measured in the present work, spin and parity are thus not yet determined. This type of band was also found in ^{79}Kr [12, 15], and their structure and energy are similar. Moreover, judging from its level energy and no parallel E2 transitions (no crossover transitions) being observed, we think that this band is probably a magnetic rotational band. In ^{79}Kr, the corresponding band starting at the second $17^-/2$ state is suggested as a non-collective band excited by three-quasiparticles to form oblate deformation, and its proposed configuration is a $g_{9/2}$ neutron coupled to a $g_{9/2}$ proton and a proton in $p_{3/2}$ or $f_{5/2}$ state, i.e. $\pi[(g_{9/2})_{9/2^+} \otimes (p_{3/2} \oplus f_{5/2})_{3/2^-}]_{6^-} \nu(g_{9/2})_{5/2^+}$ [12]. The electromagnetic transitions between these states will be of Ml character since the collective B(E2, $\Delta I = 2$) rates vanish in the limit of $\gamma = 60°$. We guess that in ^{77}Kr this band has a similar configuration and shape. Negative-parity 3qp bands have also been found in ^{81}Kr [16] and ^{83}Kr [17] which, however, start with a $13^-/2$ state and include cross-over E2 transitions. These bands were also interpreted as one-neutron-two-proton excitations. Recently, an updated level scheme of ^{81}Kr was reported by Mu et al [18]. Three nearly degenerate negative-parity bands with the $\pi g_{9/2}(p_{3/2}, f_{5/2}) \otimes \nu g_{9/2}^{-1}$ configuration have been identified and interpreted as pseudospin-chiral triplet bands with triaxial deformation. The level energy and the regular level intervals of these 3 bands are also similar to those of the M1 bands in ^{77}Kr and ^{79}Kr; however, the bands in ^{81}Kr include cross-over E2 transitions. The transition of cross-over E2 gamma-rays from being present in ^{81}Kr to being absent in ^{79}Kr corresponds to a change in the shape of the nucleus.

CONCLUSION

In the present work, high-spin states in ^{77}Kr have been populated in the reaction ^{16}O+^{68}Zn at a beam energy of 80 MeV. By analyzing the γ-γ coincidence data, one new band is observed. The regular level intervals of this band are quite similar to the magnetic rotational band, so it is proposed that this band is a magnetic rotational band, and it may be interpreted as a non-collective structure corresponding to an oblate shape involving a configuration of the type given above.

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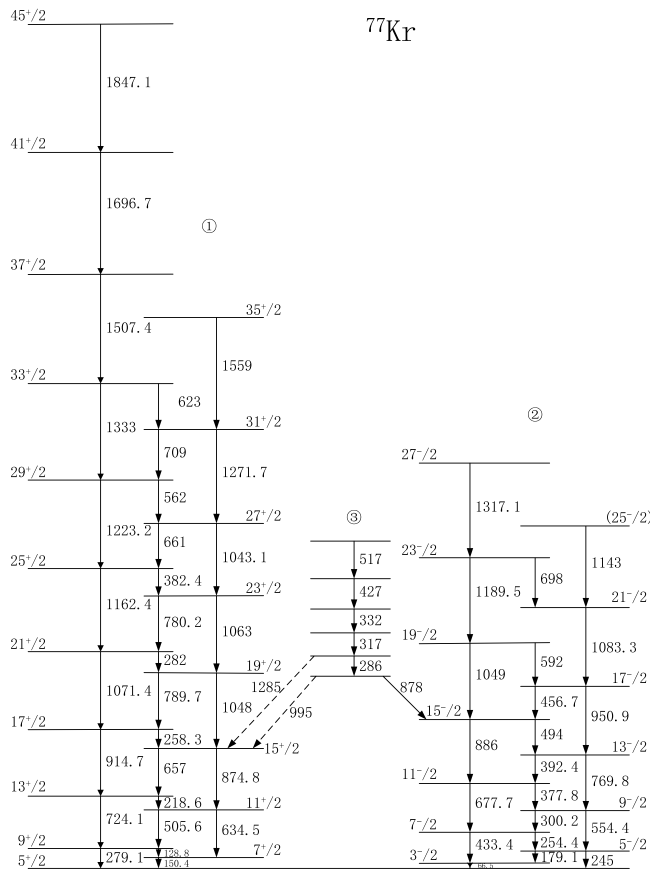

Fig. 1 A partial level scheme proposed in the present work.

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