BRIEF REPORTS

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Identification of new negative-parity levels in ^{152,154}Nd

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From an experiment with Gammasphere and a ^{252}Cf spontaneous fission source, a new negative-parity band in ^{154}Nd and new negative-parity levels in ^{152}Nd were identified and the yrast bands were extended to 18^+ in ^{154}Nd and 20^+ in ^{152}Nd in a triple gamma coincidence study. These new negative-parity bands are consistent with octupole vibrational mode. There is a constant difference as a function of spin between the J_1 values for the negative-parity band in ^{152}Nd and J_1 for the similar negative-parity band in ^{154}Nd, however, their J_2 values are essentially identical. These bands indicate a new kind of identical band. [S0556-2813(98)01004-8]

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The neutron-rich neodymium ($Z=60$) nuclei with $A \geqslant 142$ are situated at the important intersection of two transitional regions: the transition from spherical to prolate quadrupole deformation and the transition from octupole vibrational excitations to the static octupole deformation [1–6]. So far little is known about octupole excitation states in the neutron-rich nuclei in contrast to the considerable data on quadrupole collectivity [5,7]. Studies on octupole vibrational excitations in neodymium nuclei can provide tests of relevant nuclear models.

Our previous studies [5,8] in neutron-rich nuclei in the $A \sim 155$ region revealed both identical moments of inertia (kinetic and dynamic) and identical gamma-ray energies in some cases. Therefore it is very interesting to identify possible sidebands in neodymium nuclei, looking for phenomena connected to identical bands as well as octupole deformation. In ^{144,146}Ba identical octupole bands associated with stable octupole deformation were observed [5,9].

The new levels in ^{152,154}Nd were obtained from the analysis of γ-ray spectra produced in the spontaneous fission of ^{252}Cf. A detailed description of the experimental procedures and analysis methods can be found in Ref. [5] and Ref. [10].

The new transitions assigned to ^{154}Nd were identified by setting double gates on the known yrast transitions in ^{154}Nd from Ref. [5] and making sure that whenever a double gate was set on the new transitions, one not only observes the transitions corresponding to the partners (^{94,95,96}Sr) of ^{154}Nd with 4, 3, and 2 neutrons emitted, respectively, but also obtains the same yield ratios for their partners as obtained from double gating on the well known yrast transitions in ^{154}Nd. Figure 1 shows two partial coincidence spectra obtained by

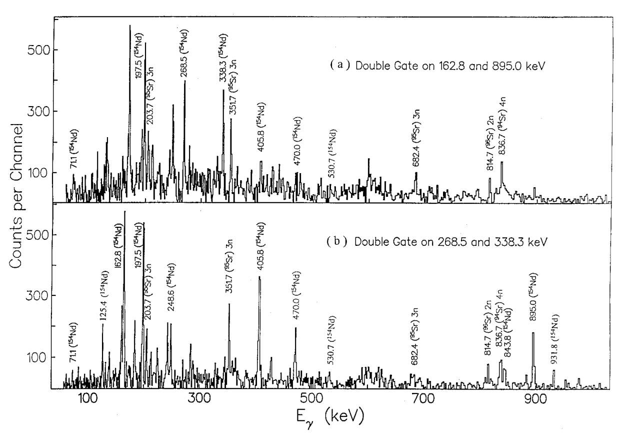

FIG. 1. (a) Coincidence spectrum obtained by double gating on the 162.8 and 895.0 keV transitions in ^{154}Nd. (b) Coincidence spectrum obtained by double gating on the 268.5 and 338.3 keV transitions in ^{154}Nd.

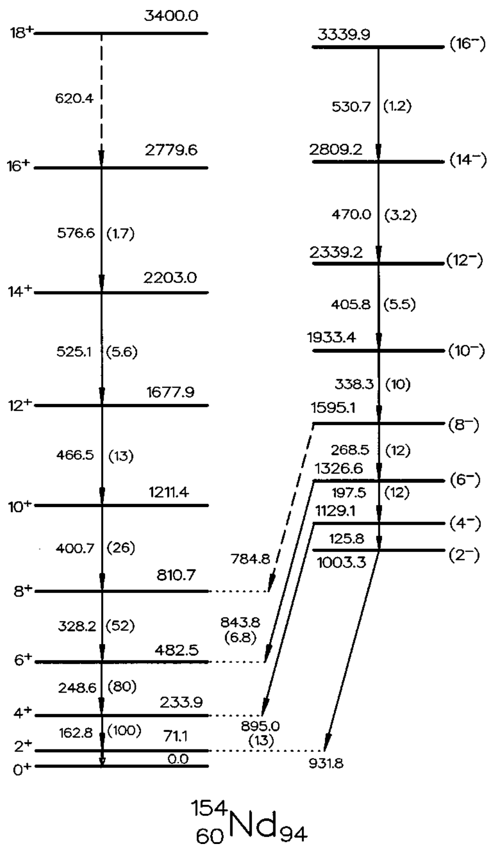

FIG. 2. Level scheme of ^{154}Nd.

setting two double gates on the transitions of energies 162.8 and 895.0 keV and 268.5 and 338.3 keV, respectively. A new level scheme of ^{154}Nd built by using our present data is shown in Fig. 2.

Based on the branching of the two lowest members of the new sideband at 1129.1 and 1326.6 keV, to only the 4^+ and 6^+ levels of the ground state band, their spins and parities are assigned 4^- and 6^-, respectively (see Fig. 2). If one assigns the new band a different set of spins, e.g., if the 1129.1 keV level were 5^-, one would expect an $E1$ transition from this level to the 6^+ level in competition with the energetically more favored one to the 4^+ level. But such a high energy $E1$ transition was not observed to the 4^+ level. If one tries to assign positive parity to the sideband, then one would expect an $E2$ transition from the 1129.1 keV to the 2^+ in the ground band. However, it is likewise not seen. Because of the lack of any crossover transitions as is typical for aligned bands, the observed level sequence is assigned as a $\Delta I = 2$ band with I^π $(2^-, 4^-, 6^-, \ldots)$. Further support for these assignments comes from the very similar energies of the transitions in this band compared to those of the established 2^- and 4^- levels in ^{152}Nd. This new nonyrast band in ^{154}Nd was observed to (16^-).

In ^{152}Nd, in addition to the yrast band, several negative parity bands have already been identified from earlier studies [11]. The seven levels at 1239.0, 1405.9, 1541.8, 1600.3, 1683.3, 1826.7, and 1898.1 keV were observed in the earlier β-decay studies of ^{152}Pr [11] and confirmed in this work. The spins and parities of these levels have already been assigned as shown in Fig. 3 [11]. By double gating on these transitions as well as known yrast transitions in ^{152}Nd, we have extended the band from the known 2^- and 4^- to 12^- levels and added a 5^- level at 1782.7 keV to ^{152}Nd as well as extending the yrast band to 20^+. The level scheme built by using the present coincidence relationship is shown in Fig. 3.

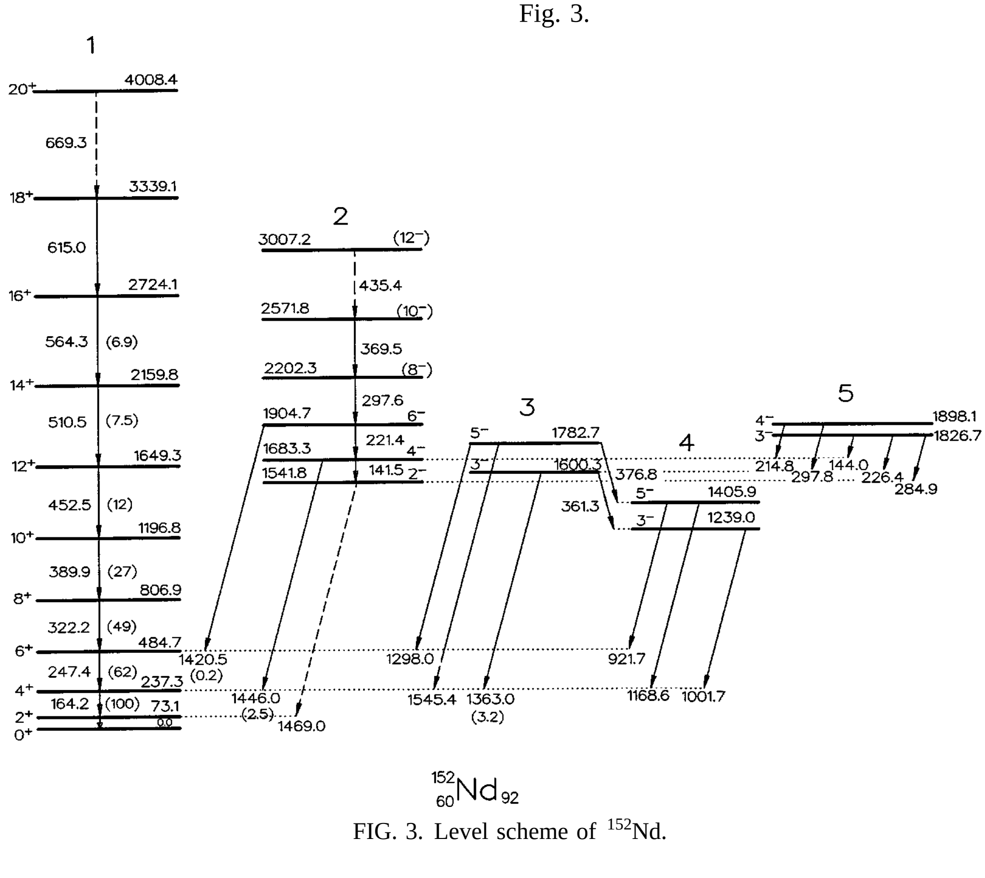

FIG. 3. Level scheme of ^{152}Nd.

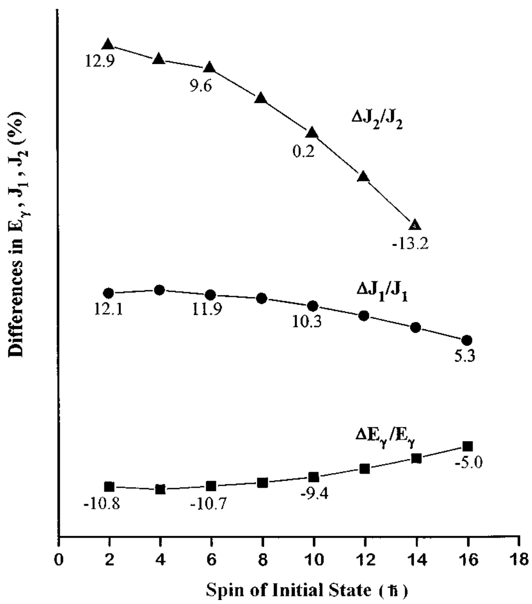

FIG. 4. Differences in transition energies and moments of inertia for the yrast bands in ^{152}Nd and ^{154}Sm.

Likewise based on the branching of the new 1905 keV level including its cascade into the established 4^- level [11], its spin and parity was assigned 6^-. The 2202, 2572, and 3007 keV levels were assigned to be the 8^-, 10^-, and 12^- members of the band built on the 1541.8 keV 2^- level, respectively. The 1782.7 keV level is assigned 5^- based on its decay to the 4^+ and 6^+ levels. It is very interesting that these 2^-, 3^-, 4^-, and 5^- levels in ^{152}Nd have such similar level energies to the known levels 2^- to 5^- levels at 1515.2, 1584.6, 1661.9, and 1774.2 keV in ^{154}Sm, respectively [12]. The yrast bands in ^{152}Nd and ^{154}Sm have transition energies and moments of inertia that are essentially identical from $2^+ \rightarrow 0^+$ to $10^+ \rightarrow 8^+$ when shifted by a constant amount 10–12 % in energies as shown in Fig. 4. The negative parity bands have even more constant and smaller shifts for the $4^- \rightarrow 2^-$ and $5^- \rightarrow 3^-$ transition energies. The percentage differences $(E_{152} - E_{154})/E_{154}$ in these transitions are 3.6% and 3.8%, respectively.

The moments of inertia (J_1 and J_2) of the ground state bands (gsb) and the negative parity bands (npb) in ^{152,154}Nd are shown in Fig. 5. While the J_1 curves for the npb in ^{152,154}Nd are similar in shape to the gsb, the J_1 curves for the gsb increase much more rapidly with increasing spin than do those of the npb. It is very interesting to note that although there is a considerable difference between J_1 for the npb in ^{152}Nd and J_1 for the npb in ^{154}Nd, their J_2 values are nearly identical and the data suggest they keep this trend even to higher spins. The J_2 curves for both the gsb and the npb are nearly identical except at the highest spin. The J_2 curves for the npb cross the J_2 curves for gsb at intermediate spins and may diverge from the gsb at higher spins. These bands indicate a new type of identical band where there is a constant difference in E_γ and J_1 for the gsb and the npb, and the J_2 for the npb and the gsb are identical.

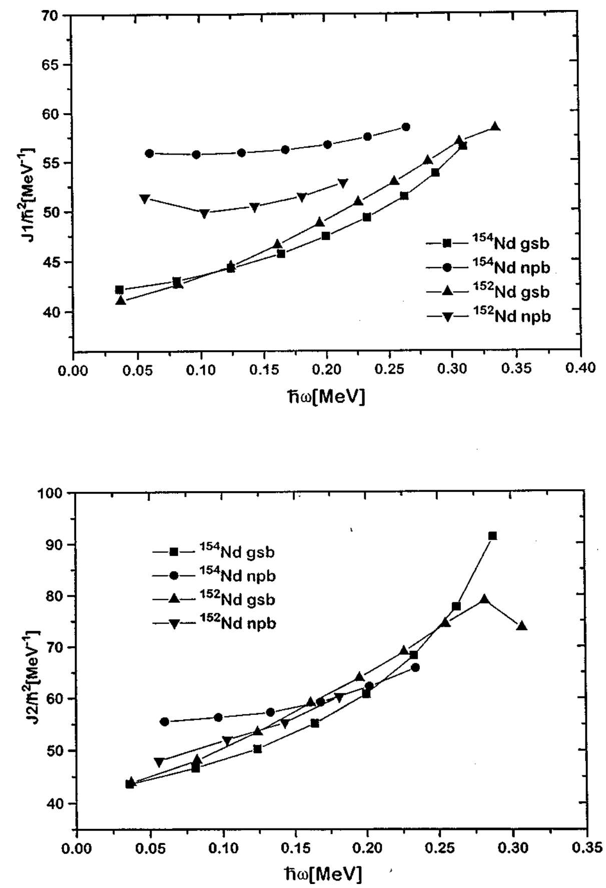

FIG. 5. Plot of the moments of inertia (J_1 and J_2) as a function of rotational frequency $\hbar\omega$ for ^{152,154}Nd isotopes.

In summary, we identified a new negative-parity band in ^{154}Nd, new negative parity levels in ^{152}Nd, and extended their yrast bands to 18^+ and 20^+. These new octupole vibrational type excitation levels may provide new opportunities to test the calculations about the octupole vibration mode.

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