38. High-Spin Spectroscopy For Odd- Z Nuclei With $A \approx 160$

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ABSTRACT

Experimental routhians, alignments, band-crossing frequencies, and the $B(M1)/B(E2)$ ratios of the $N = 90$ isotones and several light Lu ($N = 90-96$) isotopes are summarized and discussed in terms of shape changes. This systematic analysis shows a neutron- and proton-number-dependent quadrupole and $\gamma$ deformations for these light rare-earth nuclei. The stability of the nuclear deformation with respect to $\beta$ and $\gamma$ is also found to be particle-number dependent. Such particle-number dependent shapes can be attributed to the different locations of the proton and neutron fermi levels in the Nilsson diagrams. Configuration-dependent shapes are discussed specially concerning the deformation difference between the proton $h_{9/2}1/2^{-}[541]$ and the high-$K$ $h_{11/2}$ configurations. The observed large neutron band-crossing frequencies in the $h_{9/2}1/2^{-}[541]$ configuration support the predicted large deformation of this configuration but cannot be reproduced by self-consistent, cranked-shell-model calculations. Lifetime measurement for $^{157}$Ho, one of the nuclei that show such a large $h\omega_c$ in the $1/2^-[541]$ band, indicates that deformation difference can only account for 20% of such shift in $h\omega_c$.

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38.1 INTRODUCTION

Much spectroscopic information exists for the near-yrast states at high-angular momentum in the rare-earth region. Most of these investigations, however, concentrate on the study of even-even and odd-\(N\) nuclei; for example, the series of ytterbium nuclei.\(^1\)-\(^5\) Such studies provide an understanding of many high-spin phenomena, such as rotational band crossings due to the excitation of pairs of quasi-neutrons and quasi-protons; the quenching of static neutron pair correlations at high angular momentum; and the dependence of the nuclear shape on particle number, configuration, and rotational frequency.

It is important to extend such high-spin studies to odd-\(Z\) nuclei in order to establish the spectrum of proton states at large angular momentum. Many phenomena—for example, the variation of the nuclear shape induced by the occupation of various single-proton orbitals with different deformation-driving forces—can be studied and compared with the corresponding neutron effect. Furthermore, because of the large \(g\) factors associated with the unpaired proton, it is possible to investigate the details of the nuclear wave-functions by studying the magnetic-dipole transition probabilities between the favoured and unfavoured signature sequences of specific configurations.

A series of experiments have been carried out recently to study the odd-\(Z\) light rare-earth nuclei; e.g., \(^{161}\text{Lu}\),\(^6\) \(^{165}\text{Lu}\),\(^7\)-\(^9\) \(^{167}\text{Lu}\),\(^10\) and \(^{157}\text{Ho}\).\(^11\) Together with the existing data for another odd-\(A\) Lu isotope, \(^{163}\text{Lu}\),\(^12\) and the odd-\(Z\), \(N = 90\) isotones, \(^{159}\text{Tm}\),\(^13\)-\(^16\) and \(^{157}\text{Ho}\),\(^17\)-\(^19\) the newly-measured data make the odd-\(A\) lutetium isotopes and the \(N = 90\) isotones the best studied odd-\(Z\) isotopic and isotonic chains at high spin. A systematic analysis on these isotopes and isotones can therefore be made for specific configurations.

The spectroscopy for quasi-proton configurations would be identical for all the Lu isotopes in the absence of mean-field changes, since the proton configurations are the same for all the isotopes. Changes of the single-proton-state spectrum as a function of neutron number are particularly sensitive to changes in the nuclear shape. This sensitivity, combined with the variety of proton orbitals (both down- and up-sloping orbitals on the Nilsson diagrams) in this mass region, leads to a very detailed and interesting spectroscopy for these nuclei. The heaviest Lu isotope, \(^{167}\text{Lu}_{90}\), is the most stably-deformed nucleus discussed in this work. The rotational effect on single-proton motion is exhibited in this nucleus with the least ambiguity. As a result, this nucleus sets a benchmark for such a study in a stably-deformed system. With the decrease of neutron number, both the magnitude and stability of the nuclear deformation are expected to decrease. The lightest Lu isotope, \(^{163}\text{Lu}_{90}\), is near the transitional region where the nuclear deformation changes from prolate to spherical shape. Consequently, it is least stable with respect to deformations. In such a "soft" system, configuration- and angular-momentum-dependent nuclear shapes are expected. The rotational modification of single-proton motion in a "soft" system can also be investigated and compared with the more stably-deformed system.

Combined with the data of even-even, \(N = 90\) isotones, \(^{162}\text{Hf}\),\(^20\) \(^{160}\text{Yb}\),\(^1,4\) and \(^{158}\text{Er}\),\(^21\)-\(^22\) the odd-\(Z\), \(N = 90\) isotones make the \(N = 90\) isotonic chain the best studied isotonic chain at high spin. A systematic study of these isotones allows the investigation of nuclear shapes influenced by the changing mean field due to the change of proton fermi surface.

Figure 1 is a map of the nuclei to be discussed. The contrasting locations of proton and neutron fermi levels on the Nilsson diagrams (see Fig. 2, Refs. 23,24) for these two chains of nuclei (in the upper and lower portions of the shell, respectively) make the comparison of isotopic and isotonic systematics most sensitive to the configuration and particle-number dependent shapes.