Negative-parity states and β decays in odd Ho and Dy nuclei with $A = 151, 153$

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(Received 18 December 2007; revised manuscript received 5 February 2008; published 13 March 2008; corrected 31 March 2008)

We investigated the negative-parity states and electromagnetic transitions in ^{151,153}Ho and ^{151,153}Dy within the framework of the interacting boson fermion model 2 (IBFM-2). Spin assignments for some states with uncertain spin are made based on this calculation. Calculated excitation energies, electromagnetic transitions, and branching ratios are compared with available experimental data and a good agreement is obtained. The model wave functions were used to study β decays from Ho to Dy isotones, and the calculated log ft values are close to the experimental data.

DOI: 10.1103/PhysRevC.77.034303 PACS number(s): 21.60.Fw, 23.40.Hc, 27.70.+q

I. INTRODUCTION

The interacting boson model (IBM) has been remarkably successful in describing the collective phenomena observed in even-even medium to heavy mass nuclei [1–3]. In the simplest version of this model, the IBM-1, the nuclear properties are described by a system of a fixed number of bosons. In this version no distinction is made between proton bosons and neutron bosons; therefore, all states in IBM-1 are F-spin symmetric [4–6]. The building blocks are $(s^\dagger, \tilde{s})$ for s bosons and $(d^\dagger, \tilde{d})$ for d bosons. The second version, IBM-2, does distinguish between proton bosons and neutron bosons. The states in IBM-2 include all the F-spin symmetric states as well as mixed symmetry states belonging to the U(6) representation $[N-1, 1]$. An important property of this new version is that the proton-neutron symmetry character of each state is specified in terms of a new quantum number called F-spin [7–11]. For lighter nuclei, the IBM has been extended to the interacting boson model with isospin (IBM-3) [12]. Within IBM-3, the neutron-proton pair must be included in addition to the two other types of bosons in IBM-2, and they then form an isospin triplet [13–17]. In the interacting boson fermion model (IBFM) [18], odd-A nuclei are described by coupling the degrees of freedom of odd particles to a core that is described in the IBM. Calculations of positive- and negative-parity states and the electromagnetic transitions of odd mass nuclei have been performed within the framework of the IBFM, for instance, in Refs. [19–24]. One of most important properties in nuclear structure study is the β decay rate. The β transition for odd-nuclei has received intense interest in the last few years [25–32]. Theoretical contributions to the study of nuclear β decay have been made over the years using the IBFM [33–35], and good agreement has been found with the available experimental data.

The purpose of the present work is to investigate the negative-parity states and electromagnetic transitions in the ^{151,153}Ho and ^{151,153}Dy isotopes by using the IBFM-2 model. More importantly, β decay between the levels is studied by using the wave functions obtained from the structure calculation of this model. In particular, the influence of different values of Hamiltonian parameters on the energies and decay probabilities is investigated.

To calculate an odd-nucleus in the IBFM-2 model, we need to choose an even-even core. Here, the even-even ^{150,152}Dy nuclei have been chosen as the respective core for ^{151,153}Dy isotopes. They have 66 protons in the 50–82 shell and 84 and 86 neutrons in 82–126 shell, respectively. Both nucleons lie in the first half shell; therefore, they should be considered as particle bosons. For ^{151,153}Ho isotopes, we considered them as resulting from coupling a proton hole to the even-even Er nuclei.

In Sec. II, we briefly review the interacting boson fermion model. In Sec. III, we present our calculation results for the energy levels of the core nuclei and compare them with the available data. The negative-parity states of ^{151,153}Ho and ^{151,153}Dy nuclei are presented in Secs. IV and V, respectively. A discussion of electromagnetic transitions follows in Sec. VI. In Sec. VII the β decay from levels of odd-proton Ho isotopes to levels in odd-neutron Dy isotopes is studied. Finally, in Sec. VIII we summarize our results.

II. THE IBFM-2 MODEL

The low-lying levels in odd nuclei are described as a combined system of a group of bosons with one fermion. In general, the Hamiltonian for this coupled system can be written as [34]

$$H = H_B + H_F + V_{\mathrm{BF}}. \quad (1)$$

Here H_B is the usual IBM-2 Hamiltonian that describes the system of (s_ν, s_π) and (d_ν, d_π) bosons

$$H = \varepsilon_d(\hat{n}_{d\pi} + \hat{n}_{d\nu}) + \kappa_{\pi\nu}\hat{Q}_\pi \cdot \hat{Q}_\nu + \sum_{\rho=\pi,\nu} \hat{V}_{\rho\rho} + \hat{M}_{\pi\nu}, \quad (2)$$

where ε_d is the d-boson excitation energy, and $n_{d\pi}$ and $n_{d\nu}$ are the neutron and proton d-boson number operators, respectively. $\kappa_{\pi\nu}\hat{Q}_\pi \cdot \hat{Q}_\nu$ is the quadruple interaction between proton and neutron bosons, and $\hat{Q}_\rho$, the quadruple operator, is

