β^+ decay ^{203,205}At → ^{203,205}Po in the framework of the interacting boson fermion model

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The energy states and electromagnetic transitions of even-even $^{202-206}$Po and odd-mass ^{203,205}Po and ^{203,205}At isotopes within the framework of the proton-neutron interacting boson model (IBM-2) and its extension (IBFM-2) are calculated. For odd-A nuclei, the $0h_{9/2}$, $1f_{7/2}$, $1f_{5/2}$, $2p_{3/2}$, $2p_{1/2}$ and $0i_{13/2}$ single-particle orbits are considered as model space. The obtained results are used to assign spins to some uncertain spin states. The $\log ft$ values of the allowed β decay are calculated using the model wave function and compared with available experimental values.

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I. INTRODUCTION

The nuclear structure of heavy nuclei ($Z > 82$) has not been investigated enough compared to that of other heavy nuclei. Oros *et al.* [1] studied the shape coexistence in the $^{192-210}$Po isotopes. The $^{202-210}$Po isotopes were described within the parameters of the particle-core model (PCM). In these nuclei, regular protons and neutrons (one proton boson and neutron-hole boson number according to the 126 closed shell) play an important role in determining excitation energies. In the light Po isotopes, the 0_2^+ states were identified by the assignment of a 4p-2h structure. For $^{192-200}$Po isotopes, the low-lying energy levels were calculated by a 2p-2h excitation (three proton bosons) using the interacting boson model with mixing Hamiltonian.

The shape coexistence, intruder $J^\pi = 0^+$ states and the collective band structures of the light Po isotopes which are associated with the oblate proton 4p-2h intruder were investigated in Ref. [2]. Caurier *et al.* [3] have implemented the large-scale shell model space $\pi(0h_{9/2}, 1f_{7/2}, 0i_{13/2}, 2p_{3/2}, 1f_{5/2}, 2p_{1/2})$ to study the structure of $N = 126$ Po-Pu isotones. For ^{208,210}Rn and ^{206,208}Po isotopes, shell model calculations are performed in Ref. [4]. The results show that the valence neutron excitation is crucial for identifying the structure of the low-lying levels, and the $0h_{9/2}$ proton pair is required for the excited states $J^+ > 8^+$.

The low-lying states and electromagnetic transitions of $^{196-202}$Po were measured using the Coulomb excitation [5]. The measured data were compared with three models: the calculation beyond-mean-field model, the interacting boson model, and the general Bohr-Hamiltonian model. With regard to ^{200,202}Po isotopes, the transitional and diagonal matrix elements of the first $J^\pi = 2^+$ level were calculated. Large-scale shell-model calculations with six single-particle orbitals between 82 and 126 closed shells are performed. For even-even, odd-mass, and odd-odd nuclei of Pb, Bi, Po, At, Rn, and Fr isotopes, many isomeric levels are investigated in terms of the model configurations [6]. The lifetimes of $5/2_1^-$, $9/2_1^-$, and $11/2_1^-$ states, as well as the electromagnetic transitions in ^{209}Po isotope, were measured in the β decay of ^{209}At [7]. The lifetimes of the first excited $J^\pi = 2^+$ and 4^+ states of ^{208}Po isotope were measured in the α-transfer ^{204}Pb(^{12}C, ^{8}Be) ^{208}Po reaction [8]. Recently, Shukla *et al.* [9] performed a systematic large-scale shell-model calculation using a KHH7B interaction in a model space around ^{208}Pb. The energy spectra, electromagnetic properties, wave-function configurations, and isomeric states were studied in detail.

In this paper, the basic concepts, Hamiltonian, and transition operators of the interacting boson models IBM-2 and IBFM-2 are explained in Sec. II. Low-lying energy states of the even $^{202-206}$Po and odd-A ^{203,205}Po and ^{203,205}At isotopes are presented in Sec. III. In Sec. IV, the transition probabilities and branching ratios are calculated using the wave function of initial- and final-energy states. In Sec. V, the $\log ft$ values of the allowed β decay from states of odd-Z At isotopes to states in odd-N Po isotopes are calculated.

II. THE INTERACTING BOSON-FERMION MODEL

The spectrum of the odd-A At and Po ($A = 203$ and 205) isotopes can be investigated by the Hamiltonian of the interacting boson fermion model [10]

$$H = H_B + H_F + V_{BF}, \tag{1}$$

where H_B denotes the IBM-2 Hamiltonian for the even-even core nuclei. The term H_F is the odd-nucleon Hamiltonian. The third term is boson-fermion interaction.

The IBM-2 Hamiltonian can be written as

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