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Nuclear Physics A 933 (2015) 1–15

NUCLEAR PHYSICS A

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# Negative parity low-spin states of even–odd $^{187-197}$Pt isotopes

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Received 27 July 2014; received in revised form 25 August 2014; accepted 30 August 2014

Available online 3 September 2014

**Abstract**

In this paper, the negative parity low-spin states of even–odd $^{187-197}$Pt isotopes have been studied within the framework of the Interacting Boson–Fermion Model (IBFM-1). The single fermion is assumed to be in one of the $2f5/2$, $3p3/2$ and $3p1/2$ single-particle orbits. The calculated negative parity low-states energy spectra agree quite well with the experimental data. The $B(E2)$ values have been also calculated and compared with the experimental data. The calculated energy levels and $B(E2)$ are in good agreement with experimental data than that in the previous study for $^{195}$Pt isotope. Furthermore, the energy levels, electric quadrupole transition probabilities and the potential energy surface for even–even platinum isotopes (as core for even–odd nuclei) have been calculated within framework of the Interacting Boson Model (IBM-1). The predicted energy levels and $B(E2)$ transition probabilities results are reasonably consistent with the experimental data. The contour plot of the potential energy surfaces shows all interesting nuclei are deformed and have $\gamma$-unstable-like characters.



*Keywords:* IBM; IBFM; Energy level; Electromagnetic transition; Potential energy surface

## 1. Introduction

The nuclear structure of the platinum region has proven difficult to interpret in terms of the traditional descriptions [1]. These nuclei were characterized by shape changes between spherical

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http://dx.doi.org/10.1016/j.nuclphysa.2014.08.097

and deformed [2]. The IBM-1 has a group structure $U(6)$. The three limiting symmetries of this Hamiltonian, $U(5)$, $SU(3)$, and $O(6)$, correspond to the geometrical shapes, spherical vibrator, symmetric rotor, and $\gamma$-unstable rotor, respectively [2]. In calculations [3,4] within the Interacting Boson Model (IBM-1), platinum nuclei have been successfully treated as exhibiting the $O(6)$ symmetry [5] of this model. The IBM [6] has been successful in reproducing the nuclear collective levels in terms of s and d bosons, which are essentially the collective s and d pairs of valence nucleons with angular momentum $L = 0$ and 2 [7], respectively. One particularly important extension of the IBM-1 is the Interacting Boson–Fermion Model (IBFM-1) [8], which was proposed by Arima and Iachello [9,10] and describes odd-mass nuclei as systems of a fermion coupled to the IBM core through an appropriate Boson–Fermion Interaction. The IBM and IBFM can be unified into a super algebra $U(6/m)$, where 6 is the dimension of the boson space and $m = \sum_j (2j+1)$ for the fermion space with angular momentum $j = j_1, j_2, \ldots$. The even–odd Pt isotopes, together with the even–even Pt isotopes, were studied as an example of a $U(6/12)$ super-symmetry [11–14], in which where the odd nucleon could occupy single-particle orbits $j = 1/2$, $3/2$ and $5/2$. Detailed work has been done on the structure of the platinum nucleus in earlier years until now. The study of the geometry of the Pt isotopes found the absolute minimum of the potential for the Pt isotopes evolves from spherical to oblate and finally to prolate shapes when the neutron number decreases from $N = 126$ to $N = 104$ [15]. The interacting boson model calculations with or without the inclusion of intruder states in the even $^{172-194}$Pt nuclei, the energy spectra and absolute $B(E2)$ values up to an excitation energy of about 1.5 MeV had seem to be equally valid [16]. The shape/phase transition in Pt nuclei in terms of the IBM and the systematic of the spectra and the reduced $E2$ transition probabilities $B(E2)$ were calculated [17]. The prolate-to-oblate shape/phase transition was shown to take place quite smoothly as a function of neutron number $N$ in the considered Pt isotopic chain, for which the $\gamma$-softness plays an essential role. The evolution of the deformation parameter $\beta$ and of the isotope shifts for a chain of Pt isotopes with the IBM-CM approach had been studied [18]. The total energy surface and the nuclear shape in the isotopic chain $^{172-194}$Pt had been calculated using the interacting boson model including configuration mixing [19]. The results were compared with a self-consistent Hartree–Fock–Bogoliubov calculation using the Gogny-D1S interaction.

The aim of the present work is to do a microscopic study of the even–even and even–odd Pt isotopes within the IBM and the IBFM to give a comprehensive view of these isotopes in rather simple way. The results of the IBFM multilevel calculations for $^{187-197}$Pt isotopes will present for energy levels and transitions probabilities and will compare with the corresponding the experimental data. Also, the IBM-1 will apply to calculate the low-energy levels according to arrangement of bands (gr-, $\gamma$- and $\beta$-) and the $B(E2)$ value for even–even $^{186-194}$Pt isotopes. Then study of the nuclear structure described for Pt isotopes by using the potential energy surface $E(N, \beta, \gamma)$.

## 2. Theory

### *2.1. The Interacting Boson Model (IBM-1)*

In the simplest version of the Interacting Boson Model (IBM), it is assumed that low-lying collective states in medium and heavy even–even nuclei away from closed shells are dominated by excitations of the valence protons and the valence neutrons (i.e.: particles outside the major closed shells at 2, 8, 20, 28, 50, 82 and 126) only, while the closed shell core is inert. Furthermore, it is assumed that the particle configurations which are coupled (identical particles) together