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Shape Transition and Triaxial Interaction Effect in the Structure of $^{152-166}$Dy Isotopes

Falih H. Al-Khudair,* Abdul R. Subber, and Ashwaq F. Jaafer

Physics Department, Education College for Pure Sciences, Basrah University, Basrah, Iraq

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Abstract *The positive parity states in even-even $^{152-166}$Dy are studied systematically in the framework of the interacting boson model (IBM). A cubic term, $L = 3$, has been added to the Hamiltonian in order to produce the effect of triaxiality on the energy spectrum. The potential energy surfaces as a function of β and γ deformation parameters, for all isotopes have been produced. Energy levels and reduced electric quadrupole transition probabilities are calculated in framework of IBM with Cubic term (IBMC). All results are compared with available experimental data. It is found that these isotopes can be described by a schematic Hamiltonian in transition from U(5) (vibration) to SU(3) (rotation) dynamic symmetry.*

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1 Introduction

The experimental investigation of even-even nuclei in the region $150 < A < 200$ has been very extensive, mainly because of strong interest in the shape transition that takes place within this mass region.[1−12] A number of theoretical works have been done to investigate the shape phase transition and energy levels structure in rare-earth nuclei.[13−19] The Dy-isotopes have been thoroughly investigated with more emphasis on low-lying energy levels and the identification of the electromagnetic transition multiplets. These nuclei with $Z = 66$ and $N > 82$ are situated at end of the spherical nuclei and at the beginning of deformed nuclei region. Using IBM with two quasiparticle state, Chuu and Hsieh have studied the energy levels of $^{154-162}$Dy isotopes but only the ground-band transition rates were calculated, and was not able to reproduce the spectrum better.[20] Systematic high-spin calculations emphasising superdeformations in the ^{152}Dy region have also been carried out by Andersson *et al.*[21] The nature of the shape transition has been described by the concept of terminational bands.[22] Experimental evidence of such a transition has been made for ^{154}Dy.[23] Azgui *et al.*,[24] studied in details the temporal course of the γ-deexcitation of the ^{152,154}Dy isotopes formed in (HI, xn) reactions.

Many theoretical models were proposed to describe these nuclei; the two-qusipartlcle-plus-rotor model,[25] a cranking HFB model,[26] a statistical-decay model.[27] The dynamic pairing-plus-quadrupole model has been successful in analyzing the bands structure in$^{154-160}$Dy isotopes.[28] Sun *et al.*[29] have investigated nuclear magnetic dipole properties of ground bands and γ-vibrational bands for $^{154-164}$Dy isotopes using the triaxial projected shell model. An extended pseudo-SU(3) shell model[30] has been successfully applied in even-even dysprosium isotopes, the energy levels and their B(E2) transition strengths are studied.

To remove the discrepancy between experimental energy level and theoretical calculation, and get better fits to the excitation energies electromagnetic transition probabilities, three-body terms were including in the Hamiltonian denoted IBM+V3. The cubic term is found to depend on the asymmetry deformation parameter as a linear combination of $\cos(3\gamma)$ and $\cos^2(3\gamma)$ terms, thereby allowing for triaxiality.[31] In IBM, the general Hameltonian can not create stable triaxial shape in the potential energy surface, only the inclusion of higher order terms (three body interaction) in the IBM Hameltonian can lead to triaxial equilibrium shapes. The triaxial shapes fluid character of the nuclear system, are must effective when adding these terms to create a triaxial minimum in potential.[32−33]

In the present study of $^{152-166}$Dy investigating the excitations energy, electric quadrupole transition probabilities B(E2) and potential energy surfaces (PES) are intended. However, the main task of this work is to study the influence of cubic terms on the nuclear structure.

2 The IBM-1 Hamiltonian

The IBM describes low-lying energy levels in the even-even nuclei, starting from the symmetric coupling of boson.[34−36] In the origin version of the model the collective states can be described by a system of N_B identical bosons. These bosons are with angular momentum $L = 0$ (s-boson) and $L = 2$ (d-boson). Unitary transformation among the six components in the model (single state of s-boson and five states of d-boson). The reduction of this group leads to three dynamical symmetries (U(5), SU(3) and O(6)) corresponding to geometrical idea (spherical vibrator, deformed rotor, and γ-soft) respectively.

In IBM-1, following Hamiltonian can be used which is that called multipole expansion,[37] that describes the

*E-mail: falih9@gmail.com