Symmetry and Mixed Symmetry Band Structures in Low-lying Levels of $^{76-84}$ Kr Isotopes*

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Abstract The level structure of $^{76-84}$ Kr isotopes is discussed within the framework of Interacting Boson Model (IBM-2). One-phonon mixed symmetry states $J^+ = 2^+$ and two-phonon mixed symmetry states $J^+ = 1^+$, 2^+ and 3^+ have been identified by analyzing the wave function and M1 transitions. Special attention is paid to the occurrence of 0_2^+ which is not reproduced well by other calculations. The study of the influence of the $[d^+ d]_\pi^L \cdot [d^+ d]_\upsilon^L$ interactions on the nuclear structure of these nuclei are undertaken. The calculated results are compared with available experimental data; the results are in general good agreement.

Key words mixed symmetry states, $^{76-84}$ Kr isotopes, IBM-2

1 Introduction

In recent years, many mixed symmetry states have been found for even-even nuclei. In a given mass region, the mixed symmetry states usually show similar properties in energy and electromagnetic transition. The occurrence of mixed symmetry states has been predicted in various models, such as the geometrical model[1,2] and the Interacting Boson Model[3—5]. The interacting boson model assumes that the low-lying collective levels of nuclei are composed primarily of $J = 0^+$ and 2^+ coherent pairs of valence nucleons which are approximated by s and d boson respectively. In the original version (IBM-1), no distinction is made between proton boson and neutron boson, therefore all states are symmetric[6]. The second version the IBM-2, does distinguish between proton boson and neutron boson. The states in the new version include all symmetry states as well as mixed symmetry states belonging to the $U(6)$ representation $[N\text{-}1, 1]$. The different neutron-proton symmetries can be conveniently labelled by introducing a new quantum number called F-spin. A boson is an object with F-spin equal to $1/2$ and with projections $1/2$ and $-1/2$ for a proton and neutron boson, respectively. The two kinds of bosons form a F-spin multiplet namely $|\pi\rangle = |1/2, 1/2\rangle$ and $|\upsilon\rangle = |1/2, -1/2\rangle$. The states with, $F_{max} = (N_\upsilon + N_\pi)/2$, belong to the maximally symmetric representation $[N]$ of $U(6)$. The mixed symmetric states characterized by decreasing F-spin values, such as $F = F_{max} - 1$ belong to the $[N\text{-}1, 1]$ representation and so on[7]. The mixed symmetry states have the following signatures: weak collective $E2$ transitions to the symmetric states and strong M1 transition to symmetric states with matrix elements of order $\langle J_{FS}|M1|J_{MS}\rangle \simeq 1\mu N$. One example of the mixed symmetry states is the $J = 1^+$, which is called the scissors mode. In the IBM-2 picture, some 1^+ states arise from the proton-neu-

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