Low-lying states and isospin excitation in the Ge isotopes*

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Abstract The level structure of $^{64-70}$Ge isotopes has been studied within the framework of the interacting boson model-3 (IBM-3). The symmetry character in the proton and neutron degrees of freedom of the energy levels has been investigated. The isospin excitation states ($T > T_z$) have been assigned for the ^{64}Ge ($N = Z$) nucleus. Some intruder states in these nuclei have been suggested. The calculated energy levels and transition probabilities are in good agreement with recent experimental data. The study indicates that the Ge isotopes are in transition from γ-unstable to vibrational.

Key words IBM-3, Isospin, $Z \approx N$ nuclei, $^{64-70}$Ge isotopes

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1 Introduction

Highly improved detection capabilities have allowed the study of the nuclear structure in light and medium mass $N \approx Z$ nuclei in recent years[1—11]. Because the neutrons and protons are in the same major shells, the isospin effect plays an important role. Isospin excitation bands of nuclei in this area are characterized by the existence of large neutron-proton pairing[12—17]. The study of the nuclear structure of nuclei in this area is attracting more and more attention.

In Ge, Se and Kr isotopes, both valence protons and neutrons are in the same major-shell between shell-closures 28 and 50, and they were considered to be nearly spherical. Therefore their structure may be described by vibrational models, at least in the low energy region. However many experiments and theoretical work found that the low lying level structure of those nuclei is not a simple vibrator[18—21]. As a typical isotope in this area, the Ge isotopes present a useful testing ground for nuclear structure calculations. One interesting feature is that the structure is the strange behavior of the 0_2^+ states. The 0_2^+ and 2_2^+ states in the ^{70}Ge isotope are interesting cases. The 0_2^+ energy drops suddenly in ^{70}Ge, and continues to fall down at the ^{72}Ge isotope in which it is lower than the first $J = 2^+$ excited state. After dropping below the 2_1^+ in ^{72}Ge, its energy suddenly rises higher in ^{74}Ge. The strange behavior of this state is very rare in nuclei. It happens only in a few nuclei in the whole of the even-even isotopes in the nuclear chart, e.g. ^{72}Ge, ^{90,96,98}Zr and in ^{98}Mo nuclei and so on. The existence of the unusually low-lying excited 0^+ state around the first excited 2^+ state can not be ascribed simply as the 0^+ member of the two- phonon triplet (0^+, 2^+ and 4^+) states. Recently, Hasegawa et al.[22], have considered the configuration space ($p_{3/2}$, $f_{5/2}$, $p_{1/2}$, $1g_{9/2}$), and carried out a systematical shell model calculation for the $^{68-82}$Ge isotopes. The calculations showed that the strong enhancement of $B(E2)$ and the unusually low excitation of the second 0^+ state near $N = 40$ can be explained only with sufficient occupation of protons and neutrons in the $g_{9/2}$ orbit. This mechanism interpreted the 0^+ state as an intruder state, and it is described in the IBM by $(N-1)$ normal bosons and

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