Shell model study of even-even Xe isotopes

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There exist two prominent features in nuclei with mass $A \sim 130$. Firstly, the backbending phenomena are observed in many of the nuclei in this region. A sudden decrease of the level spacing is observed around states of spin 10^+. Secondly, the energy scheme shows a feature of γ-instability in low-lying states, which is known as a manifestation of the O(6) symmetry in the IBM[1)]. Previously there were some studies for describing the nuclei around this region, but they were only successful in low-lying states and not enough for high-spin states. In this paper we describe in a comprehensive manner states from low-lying to high-spins using the full-fledged shell model. Here results are reported only for ^{132}Xe.

Since at present large-scale shell model calculations are infeasible for medium and heavy nuclei, we need some kind of truncation schemes to describe a nucleus in the major shell between $50 \leq N(Z) \leq 82$. From experimental excitation energies of the nuclei ^{131}Sn[2)] and ^{133}Sb[3)], a relatively large level spacing is observed between $1d_{5/2}$ and $1d_{3/2}$ for both neutrons and protons. Thus we restrict single-particle orbitals to $1d_{3/2}$, $0h_{11/2}$, and $2s_{1/2}$ ($1d_{5/2}$ and $0g_{7/2}$) for neutrons (protons) under the assumption of $N(Z) = 64$ subshell closure. The single particle energies are adopted from experimental excitation energies of the nuclei ^{131}Sn for neutrons[2)]and from those of ^{133}Sb for protons[3)]. Two-body effective interactions among like nucleons are comprised of the monopole pairing, quadrupole pairing, and quadrupole-quadrupole interactions. Their force strengths are denoted as $G_{0\tau}$, $G_{2\tau}$ and κ_τ, ($\tau = \nu$ or π), respectively. They are adjusted so as to reproduce energy levels of the singly closed nuclei, ^{136}Xe and ^{128}Sn. The adopted force strengths for neutrons (protons) are $G_{0\nu} = 0.150$MeV ($G_{0\pi} = 0.200$MeV), $G_{2\nu} = 0.006$MeV ($G_{2\pi} = 0.010$MeV) and $\kappa_\nu = 0.160$MeV ($\kappa_\pi = 0.080$MeV), respectively. The effective interaction between neutrons and protons consists of the quadrupole-quadrupole interaction, and its force strength is denoted as $\kappa_{\nu\pi}$. It is adjusted for ^{132}Xe, and taken as $\kappa_{\nu\pi} = 0.160$MeV. The usage of this interaction was given in Refs. 4).

The theoretical and experimental spectra for positive parity levels are compared in Fig. 1. Energy levels of the even-spin yrast band are reasonably well reproduced, and our calculation predicts that the yrast 10^+ state should come below 8^+ states. This is consistent with the following experimental evidence. The $10^+ \rightarrow 8^+$ isomeric transitions for ^{130}Te, ^{132}Te, ^{130}Xe and ^{134}Xe were reported in Refs. 7).

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The half-lives of the 10^+ isomers are $T_{1/2} = 1.90(8)\mu$s, $3.70(9)\mu$s, 5.9(8)ns and $5(1)\mu$s for ^{130}Te, ^{132}Te, ^{130}Xe and ^{134}Xe, respectively. On the other hand, in case of ^{132}Xe, the 10^+ isomer decays to the 7^- level by the unique transition with $E3$ multi-polarity and has the long half-life of $T_{1/2} = 8.4$ms [5]. This fact indicates that our calculation yields right results along the yrast sequence, predicting the unknown 8^+ state to appear above the 10^+ state about 0.05MeV. Concerning the quasi-γ band, our calculations reproduce the energy staggering of even-odd spin states, which indicates instability of deformed potential in γ-direction.

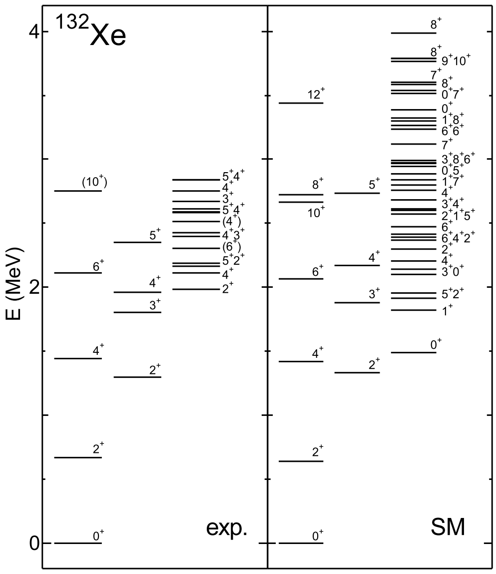

Fig. 1. Experimental energy spectra [5), 6)] (exp.) in comparison with the shell model (SM) results for ^{132}Xe.

Although details are not given here, $E2$ transition rates are also calculated. Except for the transitions $4_2^+ \to 3_1^+$ and $0_2^+ \to 2_1^+$, the calculated relative $B(E2)$ values give similar values predicted by the O(6) symmetry of the IBM. The calculated $B(E2)$ values of the yrast band give a sudden drop around states of spin 8^+, which gives a piece of theoretical evidence of the backbending caused by the alignment of $(h_{11/2})^2$ neutrons.

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