Shapes and Collectivity of Sn, Te and Ba isotopes by Coulomb excitation

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Introduction

Numerous experimental and theoretical studies are currently focused on nuclear shell structure far from the line of stability. In particular, the evolution of nuclear properties, for example, the reduced transition probabilities across the Z=50 chain of tin isotopes, has been examined in detail. This constitutes the longest shell-to-shell chain of semimagic nuclei investigated in nuclear structure to date. Radioactive ion beams yield new experimental results close to the doubly magic ^{100}Sn and ^{132}Sn, but very accurate data on the stable midshell nuclei are also of great relevance for our understanding of nuclear structure. Hence, the poorly known B(E2) values for ^{112}Sn and ^{114}Sn were re measured with high precision.

In semimagic nuclei, such as the tin isotopes, the seniority scheme provides a very valuable tool for describing the low energy spectra. But, in tellurium nuclei with two protons outside the major shell, the partial level schemes are dominated by the $1g_{7/2}$ orbit leading to 6+ isomers in the vicinity of N = 82 shell closure. For the midshell nuclei ^{120,122,124}Te one observes the expected transition to vibrational-like structure with equal energy spacings between the phonon states. This observation is in contrast to the measured quadrupole moments Q_{2+} for the doubly even Te isotopes. These quadrupole moments can reach 60% of that predicted by the symmetric rigid rotor. The aim of our investigation was to remeasure the B(E2; $0^+_{g.s}\rightarrow 2^+_1$) value in ^{120}Te with higher precision for a comparison with large-scale shell model (LSSM) calculations. In addition the investigation of reduced transition probabilities connecting higher-lying states showed astonishing results on the nuclear structure of ^{120,122,124}Te.

.Experimental Details

Most of the experiments were performed at Inter University Accelerator Centre (IUAC) in New Delhi using a ^{58}Ni beam at 175 MeV to Coulomb excite the different Sn and Te isotopes. An annular gas-filled parallel-plate avalanche counter (PPAC) was placed downstream of the target to detect both the scattered projectiles as well as the recoiling target nuclei in an angular range of $15^\circ \leq \theta_{lab} \leq 45^\circ$. De-excitation γ -rays emitted after Coulomb excitation were measured with four clover (Ge) detectors mounted at θ_γ = 135° with respect to the beam direction. To avoid any systematic errors the nucleus of interest was measured with respect to a very accurate reference nucleus.

Data Analysis

From the scattering angle (φ_p, φ_p) and the position of the Ge crystal (θ_γ , θ_γ), the Doppler-shift correction for the measured γ-ray energy was performed event by event. The excitation strength of the 2^+ state in the different isotopes were determined for distant collisions, with the first excited 2^+ state in ^{58}Ni used for normalization. To obtain the B(E2; $0^+_{g.s}\rightarrow 2^+_1$) value in ^{112,114}Sn and ^{120}Te the experimental γ-ray intensity double ratio e.g. $[I_\gamma(^{112}Sn)/I_\gamma(^{58}Ni)]/[I_\gamma(^{114}Sn)/I_\gamma(^{58}Ni)]$ of the $2^+_1\rightarrow 0^+_{g.s.}$ decays were determined. The resulting B(E2; $0^+_{g.s}\rightarrow 2^+_1$) values of 0.242(8), 0.232(8) and 0.666(20) e^2b^2 in ^{112,114}Sn and ^{120}Te, respectively, were adjusted in Coulomb excitation calculation to reproduce experimental double ratios. The reduced transition probabilities connecting higher-excited states were extracted for close collisions from the measured γ -ray yields normalized to the $2^+_1\rightarrow 0^+_{g.s}$ transition in the respective Te isotopes.

Discussion

Our deduced B(E2↑) values of ^{112,114}Sn are included in the experimental B(E2↑) systematic of Fig. 1. It is apparent that the results are about 20% larger than that for ^{120}Sn, in contrast to the symmetric distribution expected with respect to midshell A=116. The comparison between experiment and LSSM calculations shows agreement for the heavier Sn isotopes assuming ^{100}Sn as a core. However, for the lighter Sn isotopes a symmetry of the B(E2↑) systematics is observed. This indicates a different character for the core excitations in the N=Z and N>Z regions of the Sn isotopic chain.

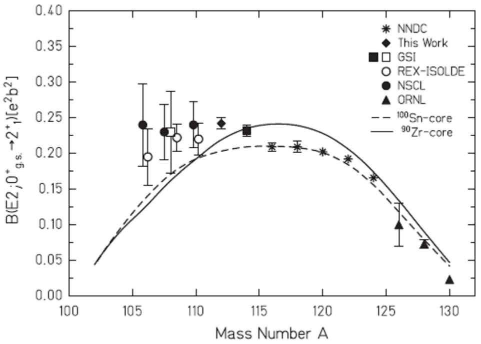

Fig. 1 Comparison of the new experimental B(E2↑) values and data from NNDC for even even Sn isotopes with LSSM calculations.

In addition, if we compare the Te and Sn isotopic chains, we note that the collectivity in tellurium is two to three times larger than for the tin data. For ^{120}Te we obtain a Weisskopf estimate of 36 s.p.u., which corresponds to 12 s.p.u. for ^{118}Sn. The difference between two proton-particle and two proton-hole configurations were investigated by plotting B(E2; $0^+_{g.s}\rightarrow 2^+_1$) values for tellurium and cadmium versus the neutron number (Fig. 2). Both distributions are almost identical, but they are again asymmetric with respect to N = 66 midshell nuclei. The observed dependence on the element number is well explained by the rotational model in which the B(E2↑) values scales with $Z^2A^{4/3}$. The dashed curve in Fig. 2 is calculated from the Cd data multiplied by $(52/48)^2$ to obtain the B(E2↑) value of a Te isotope with the same neutron number. One obtains the same dependence on the neutron number for the Te and Cd isotopic chain and a difference between particle and hole states cannot be observed.

From the B(E2↑) values connecting higher-lying states, the nuclear structure of the ^{120,122,124}Te isotopes was determined, which shows the behaviour of a soft triaxial nucleus. It clearly demonstrates that many experimental observables are needed to obtain the correct answer of the nuclear behaviour.

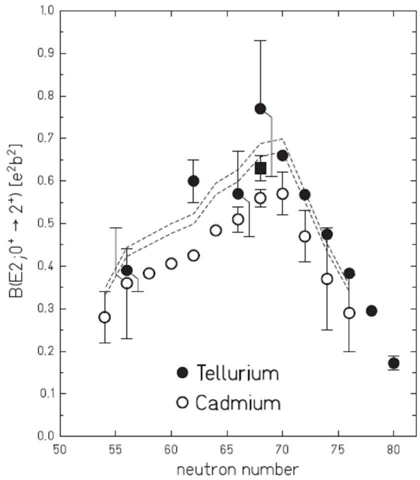

Fig. 2 Reduced transition probabilities B(E2↑) for Te and Cd isotopic chains versus the neutron number. The dashed curves are calculated from the experimental Cd data, scaled by a factor of $(52/48)^2$ in order to obtain the corresponding B(E2↑) values in Te isotopes.

The performed investigations in this mass region will be continued with similar experiments on Barium isotopes.

References

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