Z=50 shell gap near ^{100}Sn from intermediate-energy Coulomb excitations in even-mass $^{106-112}$Sn isotopes

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Abstract

Rare isotope beams of neutron-deficient ^{106,108,110}Sn from the fragmentation of ^{124}Xe were employed in an intermediate-energy Coulomb excitation experiment. The measured $B(E2, 0_1^+ \rightarrow 2_1^+)$ values for ^{108}Sn and ^{110}Sn and the results obtained for the ^{106}Sn show that the transition strengths for these nuclei are larger than predicted by current state-of-the-art shell-model calculations. This discrepancy might be explained by contributions of the protons from within the Z = 50 shell to the structure of low-energy excited states in this region.

Key words:
PACS: 25.70.De 23.20.-g

The measurements of the $B(E2, 0_1^+ \rightarrow 2_1^+)$ values for nuclei on the neutron-deficient side of the Z=50 chain, are hindered by the 6_1^+ isomeric state with a lifetime in the nanosecond range, while the expected lifetime for the 2_1^+ state is at least two orders of magnitude shorter. Therefore, for a measurement, the 2_1^+ state must be populated from the ground state. This paper reports on the results of an intermediate energy Coulomb excitation experiment with the neutron- deficient $^{106-110}$Sn isotopes obtained from the fragmentation of ^{124}Xe. A measurement for ^{112}Sn is reported as a check of consistency with existing experimental data.

In the current experiment a stable beam of ^{124}Xe was accelerated by the Coupled Cyclotron Facility at the NSCL to 140MeV/nucleon and fragmented on a 300 mg/cm^2 thick Be foil at the target position of the A1900 fragment separator [1]. A combination of slits and a 165 mg/cm^2 Al wedge degrader were used at the A1900 to enhance the purity of the fragment of interest in the resulting cocktail beam. The energies of the ^{112}Sn, ^{110}Sn, ^{108}Sn and ^{106}Sn beams were of 80, 79, 78 and 81 MeV/u respectivelly, while their purities were of 50%, 50%, 17% and 2%. The rates on the target were of 19, 21, 17 and 2 pps/pnA respectivelly.

Coulomb excitation of the above cocktail beams on a 212 mg/cm^2 thick ^{197}Au target were studied using a combination of the Segmented Germanium Array (SeGA) [2] for γ-ray detection and the S800 spectrograph for particle identification and reconstruction of the reaction kinematics [3]. For all four tin isotopes studied, a lithium-like and a beryllium-like charge state were delivered to the S800 focal plane and identified by their position on the Cathode Readout Drift Chamber (CRDC) detectors [4]. The mass and charge of the nuclei were extracted on an event-by-event basis from the time of flight and energy loss information.

In the current study the absolute Coulomb excitation cross section measurement was hindered by a loss of CRDC efficiency for certain θ angles. Therefore, the experimental information on the transition rates was extracted from a relative measurement to excitations of the ^{197}Au target. By taking the ratio of the cross sections for the Sn projectile and Au target excitations, the dependence on b_{min}, reaction kinematics and detector efficiencies in this ratio is removed, as long as safe Coulex conditions are met. The ratio of the cross sections is measured from the ratio of γ-ray intensities depopulating the 2^+_1 state in Sn and the $7/2^+_1$ state in the Au nuclei. Knowing the target $B(E2)$ [6] the corresponding transition rate for the projectile is extracted.

In view of the above, the analysis of the $^{108-112}$Sn data proceeded in the following way. A subset of particle-identified events with the impact parameter larger than 19.5 fm was selected; the corresponding measured scattering angle in the lab was 45 mrad. Next, the relative cross section ratios were obtained for the downstream ring at 37° and the ring at 90° separately, and the $B(E2)$'s in Sn nuclei were extracted.The corresponding results are listed in Table 1 [7].

The ^{106}Sn measurement was most affected by the CRDC problems. Absence of reliable angle information for a significant fraction of the collected data required a relaxation of the constraints set on the impact parameter and the scattering angles. Taking advantage of the fact that the hardware acceptance of the S800 spectrograph limits the range of the scattering angles for detected events to 60/85 mrad in the dispersive/non-dispersive direction, respectively, all the counts corresponding to ^{106}Sn were included in the cross section calculation. For all four isotopes the ratio of the projectile to the target Coulomb excitations was extracted from data gated only by the hardware gate on angle given by the S800 angular acceptance. The value of these ratios for $^{106-112}$Sn are 1.2(3), 1.16(11), 1.24(9), and 1.29(10) respectively. A common scaling factor of 0.19(1) between these ratios and the measured $B(E2, 0^+_1 \rightarrow 2^+_1)$ values was computed for $^{108-112}$Sn and applied to the ^{106}Sn; the resulting $B(E2)$ for ^{106}Sn is reported in Table 1 [7].

The ^{106}Sn result was obtained in less than ideal conditions, and we cannot safely gate out contributions to the total cross section of other processes then Coulomb scattering. Yet, the measurement gives strong indications that the $B(E2, 0^+_1 \rightarrow 2^+_1)$ is higher than expected for this isotope from structure calculations assuming a stable Z=50 shell gap

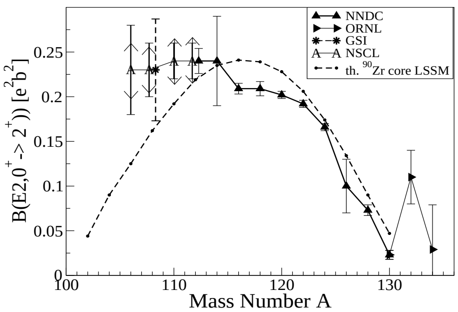

Fig. 1. Experimental $B(E2)$ in Sn from NSCL experiment and from Refs. [8–10]. The dotted line shows the predictions of the large scale shell-model calculations of Ref. [10] performed with ^{90}Zr core. For $^{108-112}$Sn the error bars represent statistical errors; the corresponding systematic errors are marked by arrows. The ^{106}Sn value is tentative, as indicated in the text.

Table 1
Reduced $E2$ transition rates measured for $^{106-112}$Sn isotopes.

Isotope	$B(E2, 0_1^+ \rightarrow 2_1^+)$ $[e^2b^2]$	Δ_{stat} $[e^2b^2]$	Δ_{sys} $[e^2b^2]$
^{112}Sn	0.240	0.020	0.025
^{110}Sn	0.240	0.020	0.025
^{108}Sn	0.230	0.030	0.025
^{106}Sn	0.240	0.050	0.030

near ^{100}Sn.

In summary, the measured nearly constant $B(E2)$ strength of $\sim$0.24 e^2b^2 in $^{108-110}$Sn isotopes together with the value for the ^{106}Sn $B(E2)$ suggested by the NSCL experiment is in disagreement with the state-of-the-art shell model predictions. This discrepancy could be explained if $g_{9/2}$ protons from within the $Z = 50$ shell contribute to the structure of low-energy excited states in this region. Such contributions are favored and stabilized by the α-like correlations for protons and neutrons occupying the same shell-model orbitals in nuclei near $N = Z$ [7]. This work is supported by the US NSF PHY01-10253, PHY-0555366 and NSF-MRI PHY-0619407. One author (C.A.) acknowledges the support from the National Science and Engineering Research Council of Canada, the Swedish Foundation for Higher Education and Research and the Swedish Research Council.

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