Triple Shape Coexistence in ^{181}Tl*

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The mid-shell Tl isotopes mimic the mid-shell Pb isotopes in that structures built on spherical, oblate and prolate shapes have been established in ^{183,185,187}Tl [1-3]. A comparison of the excitation energy of single-particle states associated with the different shapes shows that the excitation energy of the $13/2^+$ $i_{13/2}$ prolate state continues to decrease as one approaches mid-shell (N=102) while the oblate structure built on the $h_{9/2}$ orbital minimizes in excitation energy at N=108 and rises in energy with decreasing neutron number. In even-even Pb and Hg isotopes, the excitation energy of excited prolate states begin to rise in energy for N<102. For the Tl and Pb isotopes, the ground states remain spherical, but it remains an open question whether this same trend observed in the Pb nuclei for the prolate states continues beyond mid-shell for the Tl isotopes. In order to answer this question, we have a completed a study of ^{181}Tl (N=100).

Excited states in ^{181}Tl were populated with the ^{92}Mo(^{90}Zr,p) reaction using a 385 MeV beam delivered by the ATLAS superconducting linear accelerator at Argonne National Laboratory. Due to the large negative Q-value for this reaction, the compound nucleus is left with relatively low excitation energy, E^*~23.5 MeV, thus, minimizing competition from fission and multiple charged particle evaporation. Prompt γ rays were measured with the Gammasphere array consisting for this experiment of 101 large volume escape-suppressed Ge detectors. Gammasphere was used in conjunction with the Argonne Fragment Mass Analyzer (FMA) in order to separate the fusion evaporation channels produced with μb cross sections from the fission products produced at a cross section in excess of 100 mb. By utilizing the FMA, evaporation residues recoiling out of the target are dispersed at the FMA focal plane according to their mass-to-charge (m/q) ratio. A position-sensitive parallel grid avalanche counter (PGAC), located at the focal plane, provided the m/q information as well as time of arrival and energy-loss signals of the evaporation residues. The recoiling nuclei were subsequently implanted into a 40x40 strips, double-sided silicon strip detector (DSSD) located 40 cm behind the PGAC. The DSSD was used not only to detect the implantation of a residue, but also to measure its subsequent α decay. In addition, three clover detectors were placed around the DSDD in order to measure γ rays in coincidence with either implanted recoils or α decaying isotopes.

Before our investigation, only the ground state and an α-emitting isomeric state had been experimentally characterized in ^{181}Tl [4], however, the excitation energy of the excited state had not been measured. In our new study, the excitation energy of both prolate and oblate excitations relative to the ground state have been determined utilizing both prompt γ rays measured at the target, and delayed γ rays and α decays measured at the FMA focal plane. Our data show that the excitation energy of the $i_{13/2}$ prolate band in ^{181}Tl rises relative to both the spherical and oblate states, reversing the trend observed in the heavier odd-A Tl isotopes. In addition, we have observed a prolate rotational band feeding the ground state directly. We have associated this excitation with the ½[400] Nilsson configuration. It has been suggested that the lowest lying $1/2^+$ states in ^{185,187}Bi are associated with this orbital, marking a shape transition from oblate to prolate deformed shapes in the Bi isotopes [5]. Our new results and their implications to shape coexistence in this region will be presented.

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