High-spin states and isomers in ^{207}At

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1. Introduction

Nuclei in the vicinity of both the proton and neutron shell closures exhibit spherical or near-spherical shapes arising due to intrinsic degrees of freedom. However, onset of the collective excitations is evident with increasing number of valence particles or holes. In view of this, the Po and At isotopes offer a suitable ground for understanding the shape evolution. A recent study on the low-lying level structures in ^{204}Po and ^{206}Po [1] isotopes reported that the transition from single-particle to collective-excitation mode with decreasing neutron number occurs below the ^{206}Po. The lighter Po isotopes near $N \approx 112$ exhibit oblate deformed structures, and subsequently evolve into prolate deformation as the $N = 104$ neutron mid-shell is approached [2, 3]. With one extra proton, the level structures in odd-A At isotopes can be interpreted as an unpaired-proton coupled to the even-even core of the corresponding Po isotone. Hence, odd-A At nuclei are expected to exhibit structural properties and phenomena similar to the corresponding Po core, which is indeed reflected in the earlier studies.

In addition, presence of high-j valence orbitals in the vicinity of the Fermi surface in the nuclei near the heaviest doubly-magic shell closure leads to the realization of the isomeric states arising due to dominant intrinsic degrees of freedom. The study of nuclear isomers is pivotal as they provide key inputs for understanding the structure of the nuclei and to test the predictions of the shell model. Several high-spin isomers have been reported in the At and Po isotopes. The present study was focused on investigating high-spin states and isomers in ^{207}At.

2. Experimental Details

High-spin states in ^{207}At were populated using the ^{198}Pt(^{14}N, $5n\gamma$)^{207}At reaction. A self-supporting ^{198}Pt target of ~ 10 mg/cm^2 thickness and $\approx 92\%$ enrichment was bombarded by the ^{14}N ion-beam. The energy of the ^{14}N ions delivered from the 15 UD Pelletron accelerator at Inter-University Accelerator Centre (IUAC), New Delhi was varied between 80−87 MeV. The Indian National Gamma Array (INGA) was utilized to record the γ-rays emitted during the de-excitation of the residual nuclei. Two- and higher fold data were collected using VME based data acquisition system and written to a disk in ROOT [4]

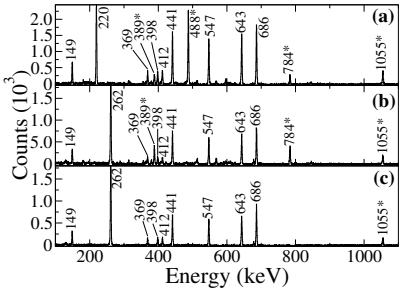

FIG. 1: The spectra illustrating the transitions in double gates of the (a) 402-, 262-keV, (b) 402-, 220-keV, and (c) 402-, 488-keV γ rays. The new transitions are marked with an asterisk.

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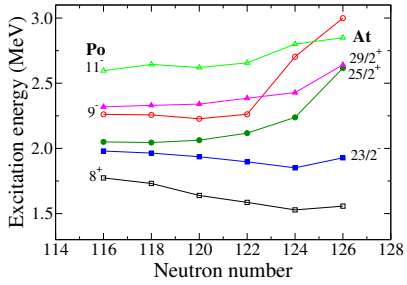

FIG. 2: Energy systematics of the selected levels in At (solid symbols) and Po (open symbols) isotopes. The level energies for the At and Po isotopes are taken from Ref. [6] and the present work. The neutron number for the ^{207}At is 122.

tree format. Further, the calibrated data were sorted into two- and three- dimensional histograms using a code developed at IIT Roorkee. These histograms were further analyzed using ROOT and RADWARE.

3. Results and Discussion

High-spin states in ^{207}At ($N = 122$) which is the subject of the present work were investigated earlier using ^{204}Pb(^{6}Li, $3n$)^{207}At reaction. A total of ten excited states up to the $25/2^+$ isomeric state [$T_{1/2}$ = 108(2) ns] at 2117 keV were established by Sjoreen *et al.* [5]. In the present study, excited levels in the ^{207}At were established up to $47/2\ \hbar$ and $E_x \approx 6.5$ MeV with the addition of about 50 new γ-ray transitions. Four new sequences consisting of about 30 new γ-ray transitions were identified for the first time which feed the known $25/2^+$ isomer. We also present an evidence of a long-lived $29/2^+$ isomer in ^{207}At, which is known in all neighboring odd-A At isotopes. The comparison of the coincidence spectra presented in Fig. 1 shows the presence of a strong 488-keV transition in coincidence with the 262- and 402-keV γ rays but not with the 220 keV, which lies above the 262- and 402-keV γ rays. This in turn suggests a new level at 2385 keV. Further, the absence of any prompt γ ray/s feeding the 2385-keV level indicates the presence of a long-lived isomeric state. The detailed results supporting the isomeric nature and the spin-parity assignment ($I^\pi = 29/2^+$) to the 2385-keV level will be presented during the symposium.

Figure 2 shows the energy systematics of the 11^- [$\pi(h^1_{9/2}i^1_{13/2})_{11^-}$], 9^- [$\nu(f^{-1}_{5/2}i^{-1}_{13/2})_{9^-}$], and 8^+ [$\pi(h^2_{9/2})_{8^+}$] states of the even-even Po isotopes and compared with the corresponding $29/2^+$, $25/2^+$, and $23/2^-$ levels in odd-A At isotones. The systematic trend in the excitation energies suggests that the structure of the $29/2^+$ and $25/2^+$ states in the At isotopes may be interpreted as coupling of the unpaired proton in the $h_{9/2}$ orbital to the 11^- and 9^- states of the corresponding Po isotones, respectively. Similarly, the $23/2^-$ state appears to originate due to a weak coupling of the unpaired proton in the $f_{7/2}$ orbital to the 8^+ state of the Po core. The shell-model calculations performed using the code NuShellX [7] with the KHM3Y effective interaction also suggest the same configurations for the above states in ^{207}At. Detailed results and the shell-model interpretation of the new states above the isomers will be presented during the symposium.

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