Observation of band structure and new isomeric levels in ^{204}At

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Introduction

Nuclear structure of proton-rich trans-Lead region of nuclear chart largely remains unexplored because of 1) the difficulty in producing these nuclei by fusion-evaporation reactions by avoiding large background contamination due to stronger and competing fission reaction channel, and 2) the difficulty in extracting the targeted information and corroborating the results from the theoretical shell model calculations, which are virtually impossible to perform for these nuclei.

High spins states of neutron deficient ^{208,210}Fr nuclei were investigated in the earlier campaigns of the INGA facility[1, 2]. A few isomeric states were found, and their spin differences were obtained from the DCO ratio measurements across the isomeric levels. The level schemes, built up for the odd-odd Francium isotopes (^{208,210}Fr) indicate that their nuclear structures can be qualitatively explained from the empirical shell model, though quite a few isomeric levels with larger life times might have escaped detection due to constraints and limitations in the experiment.

Isotopes of proton rich Astatine nuclei have not been explored in detail. Recent sudies on these isotopes have been rather incomplete in establishing their level scheme extending to high spin states. The isotopes in the proximity of $N = 120$, with both the odd proton and the odd neutron occupying high-j orbitals, have been found to exhibit magnetic rotational band structure at high angular momenta[4]. An isolated $\Delta I = 1$ band was observed, but the cross-over E2 transition(s) were not observed. Also the linking transitions to the band were not reported.

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Experiment

The experiment was done at the Indian National Gamma Array(INGA), stationed at the Pelletron Linac facility in Mumbai and has been reported earlier[3]. Analysis of the DCO ratios and polarization measurements were done from the angle dependent and clover segment based coincidence matrices. Coincidence data with time stamps were collected using a fast DSP data acquisition system based on Pixie-16 modules[5]. Time difference (ΔT) spectra were obtained from the time stamped data by setting gates on the $\gamma - \gamma$ coincidence matrices after background subtraction. These data were used to obtain the life time of the possible isomeric states.

Results and discussion

^{204}At is known to have 7^+ as ground state spin parity, with $\pi(1h_{9/2})\otimes\nu(2f_{5/2})$ configuration outside the ^{202}Po core. However, The 587 keV first excited state 10^-, with $\pi(1h_{9/2}) \otimes \nu(1i_{13/2})$ configuration is a $\sim$ 100 ms isomeric state due to the spin gap arising from the intruder neutron orbital.

The main sequence of transitions including 601, 491, 717 and 537 keV gamma rays and the $\Delta I = 1$ possible shears band-like structure

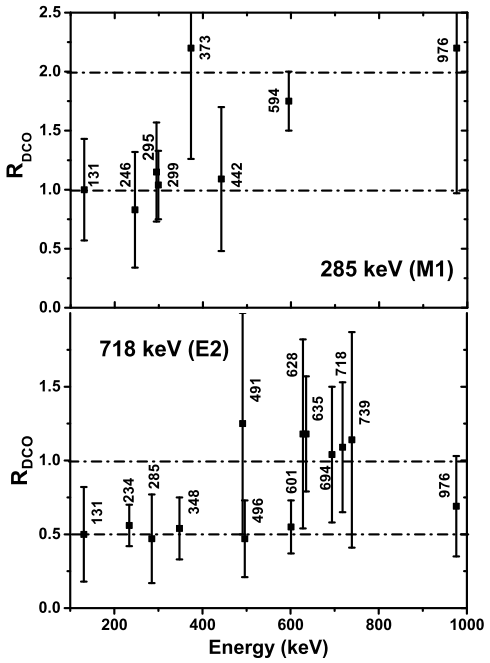

FIG. 1: DCO ratios measured with respect to 718 keV E2 and 285 keV M1 transitions in ^{204}At.

consisting of transitions involving 131, 285, 299, 296 and 246 keV gamma rays were identified by the previous workers[4]. By putting gates on the 601 and 491 keV gamma rays, and also on the Astatine X-rays, a significant number of transitions were identified, which were not observed by earlier workers. DCO ratios and polarization asymmetry results were used to estimate the multipolarity and electric or magnetic nature of the transitions (see Fig. 1).

Further investigations into the cross-correlation of the transitions reveal the main yrast sequence and new transitions belonging to the $\Delta I = 1$ band. A few new transitions linking the $\Delta I = 1$ sequence could also be observed and fitted into the level sequence. Matrices generated by gating on the time window indicate the possible presence of isomers along the linking pathway to the $\Delta I = 1$ band. Gamma ray spectra, obtained by gating on the known transitions of the $\Delta I = 1$ band, reveal 4 new cross-over transitions which confirms the $\Delta I = 1$ band. Characteristics of the weak cross over transitions are investigated.

Search for isomeric transitions, as found from the missing intensity balance, were done. A couple of transitions could be identified from the life time measurements by fitting on the gated ΔT spectra. The new isomeric levels extracted from our results are: 1629 keV with measured life time: 30.5 ± 1.2 ns and the 4018 keV level with 46.9 ± 3.1 ns life time. Based on all the above results, old and new, a tentative level scheme of ^{204}At is proposed.

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References

[1] D. Kanjilal et al., Nucl. Phys. A**842**, 1 (2010).
[2] D. Kanjilal et al., Phys. Rev. C **84**, 064321 (2011).
[3] D. Kanjilal et al., DAE Symp. on Nucl. Phys. **56**, 438 (2011).
[4] D. J. Hartley et al., Phys. Rev. C **78**, 054319 (2008).
[5] R.Palit, AIP Conf. Proc. **1336**, 573 (2011).