Systematic study of potential energy surfaces of odd mass Astatine isotopes

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Introduction

The region around Lead nuclei including the Z=82 magic shell gap offers a large variety of interesting nuclear phenomena. This includes shape coexistence, sudden change in ground state deformation and changes in the ground state spin and parity between neighbouring nuclei. When moving from N=126 shell closure toward proton drip-line and toward the N=104 neutron mid shell, a change from spherical to oblate deformed and onward to prolate deformed collective structures occur. This type of features are well known in case of even-mass Polonium isotopes [1]. Similar behaviour can be predicted for odd-mass Astatine isotopes (At), which can be imagined as an odd proton coupled to the Polonium core. Here, we report on some Woods-Saxon calculations for At isotopes.

Results & Discussion

The α-decaying ground states of the even-N At isotopes with 112 $\leq$N$\leq$ 126 have been assigned with $(\pi h_{9/2})^3$ configuration. A second α-decaying state, $\frac{1}{2}^+$, is observed in ^{197,203}At [2] and this becomes the ground state of ^{195}At. This state is said to originate from the the intruder proton $s_{1/2}$ orbital in the Nilsson diagram. One more interesting case is the presence of $\pi i_{13/2}$ configuration, which plays the key role for the origin of isomeric $\frac{13}{2}^+$ state in case of ^{197,199,201,203}At. However, no suitable experimental data are available to confirm the isomeric character of this $\frac{13}{2}^+$ state for heavy At isotopes. Rotational bands built on $\frac{13}{2}^+$ state have been observed in case of lower mass At isotopes but collectivity gradually becomes disperse with increasing neutron number, i.e for heavier At isotopes. Moreover, neutron-deficient odd mass Bi isotopes, with two protons fewer than At isotopes, are well studied indicating a strongly coupled oblate band built on $\frac{13}{2}^+$ state. We have done a systematic study of potential energy surfaces of odd-mass even-N At isotopes using Woods-Saxon potential. The Hartree-Fock-Bogoliuobov code of Nazarewich et al. [3] is used for the calculations. The Total Routhian Surface (TRS) is calculated at each $\hbar\omega$ in the $\beta_2\gamma$ plane with minimization of β_4. Calculations are done for the (π, α)=(-,+$\frac{1}{2}$) and the (π, α)=(+,+$\frac{1}{2}$) proton configurations, where π and α represent parity and signature quantum number respectively.

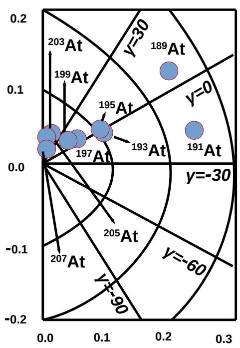

FIG. 1: A representative diagram showing the locations of energy minima for $^{189-207}$At isotopes in (β_2, γ) plane for (π, α)=(-,+$\frac{1}{2}$) proton configuration. Here x and y axes represent $\beta_2 \cos(\gamma + 30)$ and $\beta_2 \sin(\gamma + 30)$ respectively.

Here, the negative-parity, positive-signature

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configuration corresponds to a proton particle in $h_{9/2}$ shell and positive-parity, positive-signature configuration corresponds both to a proton hole in the $s_{1/2}$ shell and a proton particle in the $i_{13/2}$ shell. TRS calculations for (π, α)=(-,+$\frac{1}{2}$) configuration have predicted energy minima at near spherical shape for ^{197,199,201}At, excepting ^{189,191}At (FIG.1) - which are quite similar as were observed by K. Andgren et al. [4]. But present calculations for ^{193,195}At (FIG.2 & FIG.3 respectively) show minima which are different from previous calculations. Earlier report found oblate minima at $\beta_2 \approx 0.2$ while this calculation finds prolate minima at $\beta_2 \approx 0.11$. This is very conflicting and experimental data corresponding to structure of these two isotopes are insufficient in literature. Now at lower energy value ($\hbar\omega$=0.041 MeV), the TRS calculations for the configuration (π, α)=(+,+$\frac{1}{2}$), produce energy minima at non collective oblate shapes for higher mass ^{199,201,203}At and collective oblate shape for ^{197}At (Fig.4). Similar situation arises for ^{195,193}At, where present calculations produce energy minima at non collective oblate shape with $\beta_2 \approx 0.22$. However,

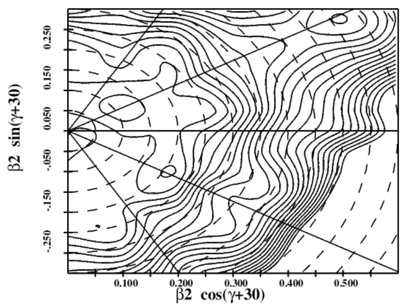

FIG. 2: TRS calculation for ^{193}At for (π, α)=(-,+$\frac{1}{2}$) configuration at $\hbar\omega$=0.041 MeV.

oblate collective minima are also appearing in the TRS plots for these higher At isotopes at slightly higher energies than the non collective minima. Hence, we conclude ^{199,201,203,205}At to exhibit coexisting collective and non collective oblate structures. Detail calculations and results will be discussed in the Symposium.

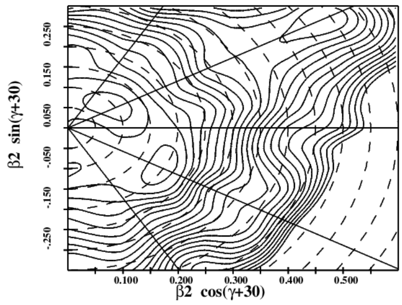

FIG. 3: Same as FIG.2 for ^{195}At.

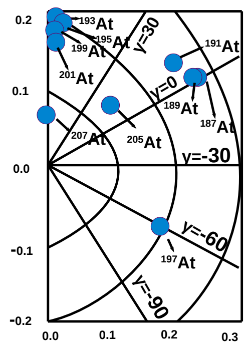

FIG. 4: Same as FIG.1 for $^{187-207}$At isotopes for (π, α)=(+,+$\frac{1}{2}$) proton configuration.

Acknowledgments

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References

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