Search for non-natural parity states in ^{213}At

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Introduction

Alpha clustering is an interesting aspect of nuclear structure. The 0_2^+ state in ^{12}C was predicted by no-core shell-model calculations at around 17 MeV [1] which is more than twice of its experimentally observed value. The existence of 0_2^+ state at 7.64 MeV (Hoyle state) has been explained by considering three alpha particles in gas-like condensate form, held together by the coulomb barrier [2]. Alpha clustering was earlier observed only in light nuclei. Recently, Astier *et al.* [3] studied the excited states in heavy ^{212}Po nucleus which has two protons and two neutrons outside the ^{208}Pb shell closure, using alpha transfer ^{208}Pb(^{18}O,^{14}C) reaction. In this experiment, two sets of states of odd and even spins with non-natural parity were reported. Also, enhanced $E1$ transitions, linking non-natural parity states and yrast states of same spin values were observed. These transitions are supposedly the signature of the presence of α-cluster structure in this system [3].

^{213}At is the isotone of ^{212}Po ($N = 128$) with one extra proton. The similarity in the low energy structure of ^{212}Po and ^{213}At is shown in Fig. 1. In the studies of the nuclei around ^{208}Pb, evidence of the spectator behaviour of the valence proton outside the $Z = 82$ core has been reported [4]. Also, the alpha-cluster preformation factor, calculated using cluster-formation model (CFM), for ^{213}At is 0.187 which is close to that of ^{212}Po (0.221) [5]. This encourages us to search for the non-natural parity states in ^{213}At.

Experimental Details

Excited states in ^{213}At were populated when ^{11}B beam, in the energy range 54-62 MeV, was bombarded on the self-supporting ^{208}Pb ($\sim$ 99% enriched) target of around 6 mg/cm^2 thickness. The beam was provided from the 15UD Pelletron accelerator at IUAC, New Delhi. The statistical model calculations (PACE4) predict very small cross-section for ^{213}At in the given reaction. However, its higher experimental yield suggests that the incomplete fusion of ^{11}B with ^{208}Pb is also responsible for the production of this nucleus. Gamma rays from the residual nuclei were detected using Indian National Gamma Array (INGA), which consisted of 14 Compton suppressed clover detectors at the time of experiment. The detectors were placed at 90°, 123°, 148°with respect to the beam direction. The two and higher fold coincidence data were acquired using CANDLE [6]. The data were first written into a ROOT Tree [7] format which were sorted to construct various 2- and 3 dimensional histograms using a code developed at IIT Roorkee. The histograms were further analysed using RADWARE [8] and ROOT.

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Results and Discussions

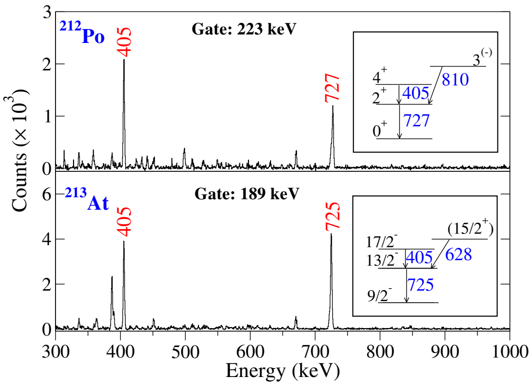

FIG. 1: Comparison of low-lying structures and corresponding spectra in ^{212}Po and ^{213}At.

Figure 1 shows a comparison of the low energy structure in ^{212}Po and ^{213}At. It is apparent from the comparison that the lowest lying two transitions have almost same energies and $E2$ nature. In the gate of 727 keV transition [Fig. 2], which is the strongest transition in ^{212}Po, a 810 keV transition of dipole nature is observed. The 3^- state which decays to the yrast positive parity 2^+ state via 810 keV transition has been understood in the framework of coupling of valence nucleon excitations to the one-phonon octupole vibration state (3^-) of ^{208}Pb core [3].

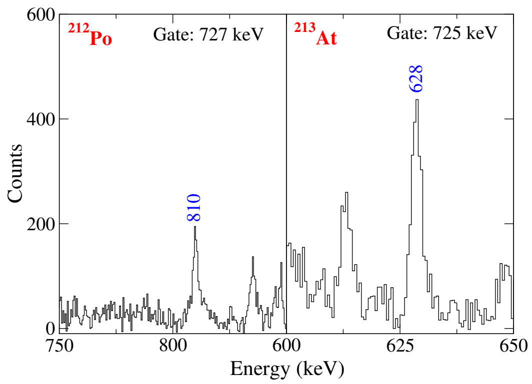

FIG. 2: Part of the spectra of ^{212}Po and ^{213}At gated by 727 keV and 725 keV transitions, respectively.

In the present study, several new transitions have been observed in ^{213}At. In the gate of 725 keV transition, a 628 keV transition is observed which decays directly to the excited $13/2^-$ state [Fig. 2]. The DCO ratio of this transition has been deduced which confirms the $\Delta J = 1$ nature and therefore, spin of 15/2 can be tentatively assigned to the level. This state can also be interpreted as the coupling of 3^- octupole excitation of the ^{208}Pb core to the excitation of valence nucleons of ^{213}At. The energy of the $(15/2^+)$ state follows the trend of decreasing excitation energy with addition of valence nucleons.

Further investigations will be carried out to search for non-natural parity states in ^{213}At. Also, unambiguous determination of multipolarities of resulting transitions, in addition to that of 628 keV transition, is desirable.

Acknowledgements

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