Revisiting isomeric states in ^{215}Fr

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Introduction

Nuclei lying in the region beyond doubly magic ^{208}Pb ($Z = 82$, $N = 126$) may exhibit two extreme modes of excitations, single particle and collective excitations. The structure of nuclei in the vicinity of ^{208}Pb display near spherical shape, while those in the region with A $\geq$ 220 have static octupole deformation and the excited states arise as a result of collective motion. The study of nuclei lying between the two regions is expected to reveal the interplay between the two modes of excitations. ^{216}Fr(Z = 87, $N = 129$) is the lightest nucleus which shows octupole correlations [1]. Therefore, a study of the ^{215}Fr($Z = 87$, $N = 128$) nucleus is interesting to assess the upper limits for the applicability of the shell model.

Decman *et al.*[2] have established the level scheme of ^{215}Fr upto 3069 keV level for the first time via in-beam spectroscopy. Two contemporary studies were carried out by Schulz *et al.*[3] and Drigert *et al.*[4] and the level scheme was extended upto 3462 keV. Isomers with half-lives ranging from 3 ns to 33 ns were also reported in the above studies. However, the half-lives of some of the isomers were found to be inconsistent. Hence, in the present study, life-time measurements were carried out using centroid shift and decay curve method. Early-delayed coincidence measurements were also performed to develop level scheme above isomers.

Experimental Details

High-spin states in ^{215}Fr were populated in the ^{208}Pb(^{11}B, 4n) reaction at Inter University Accelerator Centre(IUAC), New Delhi. In the experiment, a self-supporting target of $\sim$ 6 mg/cm^2 thickness and $\approx$ 99% enrichment was used. The beam was accelerated at 54 - 62 MeV energies by 15-UD Pellatron accelerator at IUAC, New Delhi. The Indian National Gamma Array (INGA), comprising 14 Compton suppressed clover detectors was used to detect γ rays emitted from de-excitation of the residual nuclei. The detectors were situated at 90°, 123°, 148° with respect to the beam direction. Two or higher fold coincidence data were collected using CANDLE [5]. The data were written into a ROOT Tree format and sorted into various histograms using a code developed at IIT Roorkee. These histograms were further analysed using ROOT[6] and RADWARE [7].

Results and Discussion

Figure 1 shows "early" and "delayed" γ rays in coincidence with 555.4 keV transition. Figure 1(a) depicts several new transitions which precede the 555.4 keV γ ray. A total of ten new transitions are added above the $39/2^-$

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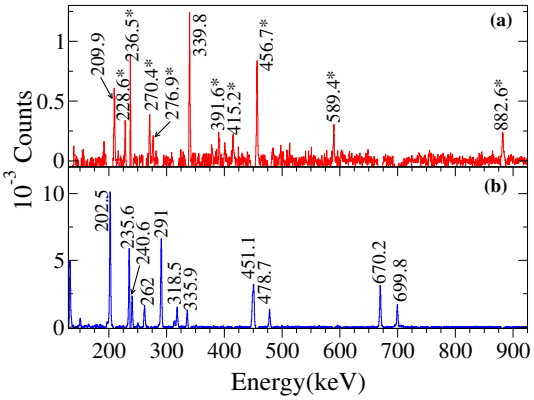

FIG. 1: Gamma-ray spectra showing (a) "early" (b) "delayed" transitions in gate of the 555.4 keV gamma ray within 50 - 200 ns time window. The new transitions are marked with asterisk.

isomeric state at 3069 keV, which constitute nine levels. This extends the level scheme upto 4770 keV and $55/2^+$ $\hbar$ angular momentum. A rotational-like sequence of 236.5-, 276.9-, 391.6 keV transitions is established, which feeds the $39/2^-$ isomeric state via the 340- and 456.7 keV transitions.

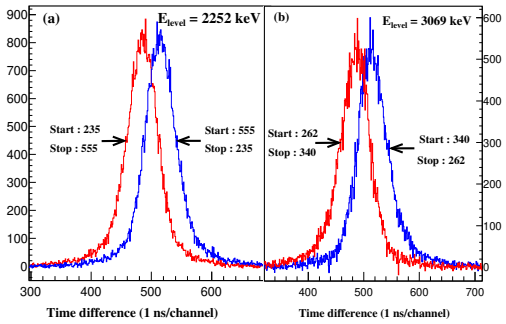

FIG. 2: Centroid shift analysis for half-life measurement of the (a) $33/2^+$ and (b)$39/2^-$ states.

Figure 2(a) illustrates the time difference spectra of the γ-ray transitions depopulating and feeding the $33/2^+$ state. This leads to $T_{1/2} \approx 10.8(10)$ ns, which is found to be greater than the adopted value of 5.3(14) ns [8]. Also, a half-life of $\sim 11.9(10)$ ns is inferred from the centroid shift analysis for the $39/2^-$ as shown in Fig.2(b), which is comparable to 14.5(14) ns measured by Schulz *et al.*[3]. Further, presence of a known shorter lived $29/2^+$ isomeric state is also confirmed. The deduced $T_{1/2} \approx 3.6(10)$ ns is found to agree well with the adopted value of 4.7(14) ns [8].

The low-lying states in ^{215}Fr suggest weak coupling of the unpaired proton to the even-even core of ^{214}Rn, which are interpreted as single particle excitations. The rotational-like sequence observed above the $39/2^-$ isomer indicates a transition to the collective nature. The detailed results along with theoretical interpretation will be presented during the symposium.

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