Evidence of a nano-second isomer in ^{201}Po

Khamosh Yadav[1],* Sahab Singh[1], D. Choudhury[1], B. Maheshwari[2], R. Roy[1], R. Palit[3], P. Dey[3], B. Das[3], A. Kundu[3], V. Malik[3], Md. S. R. Laskar[3], D. Negi[3], S. Nag[4], M. Prajapati[4], S. Jadhav[3], B. S. Naidu[3], and A. V. Thomas[3]
[1] *Department of Physics, Indian Institute of Technology Ropar, Rupnagar, Punjab-140001, INDIA*
[2] *Grand Accélérateur National d'Ions Lourds, CEA/DSM-CNRS/IN2P3, Bvd Henri Becquerel, BP 55027, F-14076 Caen, France.*
[3] *Tata Institute of Fundamental Research, Mumbai-400005, INDIA and*
[4] *Department of Physics, Indian Institute of Technology BHU, Varanasi-221005, INDIA*

1. Introduction

The long-lived nuclear states, also referred as isomers, generally occur as a result of substential difference in the structure between two nuclear states. This can be due to large difference in the angular momenta of these initial and final states and/or other degrees of freedom such as spin projection, single particle configurations, as well as small energy differences between the levels. The neighborhood of the doubly-magic ^{208}Pb is one of the important regions, rich in nuclear isomerism [1]. The Po isotopes with two proton-particles above the $Z = 82$ shell closure provide an important ground to study evolution of nuclear structure and isomerim in A $\approx$ 200 region [2–4]. A $13/2^+$ isomeric state with an unpaired neutron in $i_{13/2}$ orbital have been reported in odd-A Po isotopes with $113 \leq N \leq 123$ [2–6]. In addition to the long-lived $13/2^+$ state, three high-spin isomers, viz. $25/2^-$ [$T_{1/2}$ = 7.1(1) ns], $29/2^-$ [$T_{1/2}$ = 7(2) ns] and an isomeric level at 2158 keV [$T_{1/2} > 200$ ns] have been reported in [2, 6]. However, no high-spin isomeric states are known in ^{201}Po except the low-lying $13/2^+$ isomer with $T_{1/2} = 45(2)$ seconds. Present study reports an evidence of a nano-second isomer in ^{201}Po at 2570 keV.

Experimental Details

High-spin states in ^{201}Po were studied using the ^{195}Pt(^{12}C, 6n)^{201}Po heavy-ion fusion-evaporation reaction. The ^{12}C beam with 87 MeV energy was provided by the 14-UD Pelletron LINAC Facility at Tata Institute of Fundamental Research (TIFR), Mumbai, India. A 3.2 mg/cm^2 thick isotopically enriched ^{195}Pt target (97.3%) was utilized with a catcher foil of ^{197}Au. The γ rays emitted from the residual nuclei were detected using a hybrid array of 16 Compton-suppressed HPGe clover detectors arranged in six rings, viz. $-23°$, $\pm40°$, $\pm65°$, and $90°$ with respect to the beam direction, coupled with 14 ($2'' \times 2''$) $LaBr_3$(Ce) scintillation detectors. The list mode digital data were acquired under the two- and higher multiplicity coincidence condition using 12-bit 100 MHz PIXIE-16 digitizer modules developed by XIA-LLC, USA [7]. The calibrated data were further sorted into various two-dimentional Prompt and Early-Delayed histograms using the codes based on MultipARameter time-stamped based COincidence Search (MARCOS) [7], which were further analysed using RADWARE. Centroid-shift analysis method was used to determine half-life of the proposed isomeric state.

2. Results and Discussion

Previously, the experimental information in ^{201}Po was limited up to an excitation energy of 4153 keV and $J^\pi = (35/2^+)$ and only one long-lived isomer, $13/2^+$ with $T_{1/2} = 8.96(12)$ min was known [5]. The present study suggests evidence of a high-spin isomer in ^{201}Po in addition to the considerable extension of the level scheme. Figure 1(a) illustrates the γ-ray transitions in coincidence with 613- and 557-keV transitions. A 221-keV transition is

*Electronic address: yadavkhamosh@gmail.com

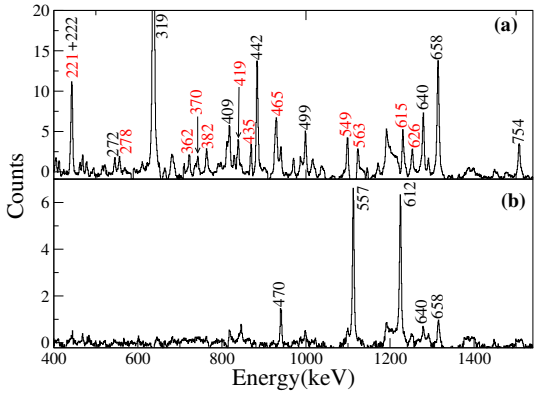

FIG. 1: The double-gated spectra illustrating the γ-ray transitions in coincidence with (a) 613- and 557-keV transitions, and (b) 754- and 221-keV transitions in ^{201}Po [5]. The new transitions are marked in red color, while earlier reported transitions are shown in black color.

newly observed in coincidence with the 613-, 557-, and 754-keV transitions. These coincidence relationships suggest it's placement above the 754-keV transition. The placement of the 221-keV transition established a level at 2570 keV. Fig. 1(b) shows γ rays in coincidence with the 754- and the 221-keV transitions. The presence of the 658-keV transition in coincidence with 754- and 221-keV transitions and intensity measurements suggest it's placement above the newly identified 221-keV γ ray. Further, Early-Delayed analysis indicates isomeric nature of the 2570-keV level, which is populated via the 658 keV and deexcites through 221-keV transition. Preliminary results of the centroid-shift analysis suggest a half-life of a few nanoseconds for the proposed isomeric level at 2570 keV.

A comparison of the newly established level structures in ^{201}Po with that in ^{203}Po [6] shows considerable similarities in the structure of the two nuclei. A $25/2^-$ isomer at 2789-keV [$T_{1/2}$ = 7.1(1)ns] has been reported in ^{203}Po [6], which is suggested to be a pure neutron state with $\pi(h^2_{9/2})_{0^+} \otimes \nu(p^2_{1/2} f^{-3}_{5/2} i^{-2}_{13/2})_{25/2^-}$ dominant configuration. The systematic similarities suggest that the proposed isomer may also have the same configuration. Detailed shell-model calculations are in progress in order to understand the isomeric nature of the level under consideration. Half-life and decay properties of the newly identified isomeric state will be presented during the symposium.

Acknowledgments

The authors thank the staff at TIFR-BARC Pelletron LINAC Facility for the smooth operation of the accelerator during the experiment. KY and DC acknowledge the financial support from the SERB-DST India under CRG (CRG/2022/005439). SS acknowledges the fellowship support from the Ministry of Human Resource Development (Government of India).

References

[1] A. K. Jain *et al.*, Nucl. Data Sheets **128**, 1 (2015).
[2] B. Fant *et al.*, Nucl. Phys. A **453** 77 (1986).
[3] V. Rakhonen *et al.*, Nucl. Phys. A **441**, 11 (1985).
[4] B. Fant and T. Weckstrom, Physica Scripta. **41**, 652 (1990).
[5] T. Weckström *et al.*, Z. Phys. A - Atoms and Nuclei 321, 231 (1985).
[6] S. Chatterjee *et al.*, Phy. Rev. C **106** 044329 (2022).
[7] R. Palit *et al.*, Nucl. Instrum. Methods Phys. Res. A **680**, 90 (2012).