Intrinsic excitations in the singly-magic ^{209}Bi nucleus

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Introduction

The region of nuclei around ^{208}Pb (with closed shells at Z = 82 and N = 126) is ideally suited for the exploration of phenomena arising from intrinsic excitations. In these near-spherical nuclei, excited states are initially generated by unpaired nucleons in valence orbitals and their mutual coupling. Once the angular momentum of the valence nucleons is exhausted, higher-lying states are obtained through excitations of the ^{208}Pb core, see *e.g.*, [1]. In both instances, residual interactions between unpaired nucleons play a role in determining which states are favored in energy over others. When a large change in angular momentum is involved in the transition from a higher to a lower excited level, or if there is a significant change in configuration, then the higher-lying state can be isomeric. These long-lived states provide an excellent testing ground for the predictions of modern, large-scale shell model calculations. Recently, we have established a large number of metastable states in Hg, Tl, Pb and Bi isotopes in the mass $A \approx 200$ region [2-7]. The above investigations have substantially advanced the understanding of the nature of the intrinsic excitations and residual interactions between unpaired nucleons. Therefore, it is of particular interest to explore excited levels and search for isomeric states in nuclei in the vicinity of the ^{208}Pb. The singly-magic ^{209}Bi nucleus, with one excess proton in comparison to ^{208}Pb, is the focus of this work.

Experiment and data analysis

Prior to this work, levels up to moderate spin in ^{209}Bi had been studied. An isomer with $T_{1/2}$ = 18 ns, having $I^{\pi} = 19/2^{+}$ and E_x = 2986 keV had been established using a ^{7}Li beam incident on a ^{208}Pb target; the emitted γ rays were recorded using two Ge(Li) detectors [8]. In this work, the g factor of this isomeric state was also measured. In subsequent work, a triton beam was used to populate levels with spin up to $I^{\pi} = 15/2^{+}$ and an excitation energy of about 3 MeV [9]. More recently, an array of high-purity germanium (HPGe) and LaBr3(Ce) scintillator detectors was used to measure lifetimes of a few low-lying states and infer $M2$ and $E3$ transition probabilities [10].

The objective of the present work was to populate highly-excited states in ^{209}Bi through multi-step Coulomb excitation using a 1.45 GeV ^{209}Bi beam from the ATLAS accelerator at the Argonne National Laboratory which was incident on a thick ^{197}Au target. The γ rays from the deexcitation of high-spin levels in ^{209}Bi were recorded by the Gammasphere detector array comprising of 100 Compton suppressed HPGe detectors at the time of the experiment. In addition to observing prompt transitions, isomeric decays in various periods ranging from nanoseconds to seconds were also recorded. Numerous histograms were generated to effectively analyze the data. These include two-, three- and four-fold symmetric energy histograms (both prompt and delayed), energy-time difference matrices generated using gates on chosen energies, angle-gated asymmetric matrices for obtaining Directional Correlation of Oriented States (DCO) ratios, among others. The data analysis was performed using the RADWARE suite of programs [11], and other software.

Results and Discussion

Since the excited states in ^{209}Bi have been populated through inelastic excitation, the production cross section is quite substantial, leading to spectra with abundant counts. The level scheme of ^{209}Bi has been significantly extended through the inclusion of several new γ rays which are found to be in cascade above the yrast transitions established from earlier work with much lighter beams [8-10]. Some of the

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new γ rays identified from the present work are indicated in Fig. 1.

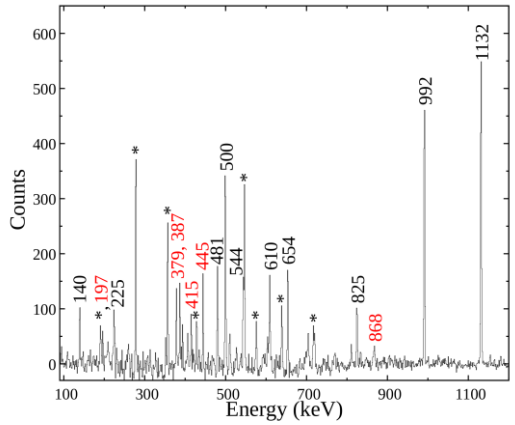

Fig. 1 Three-fold coincidence spectrum with gates on the 245 and 1608 keV γ rays in ^{209}Bi, illustrating the transitions reported earlier (in black font) and those which are newly established (in red font). The asterisks indicate γ rays from ^{197}Au, the binary reaction partner.

In addition to the prompt deexcitation of various excited levels, isomeric decays in ^{209}Bi have also been explored. One such example is indicated in Fig. 2. The presence of isomeric states other than the ones already reported is also being explored.

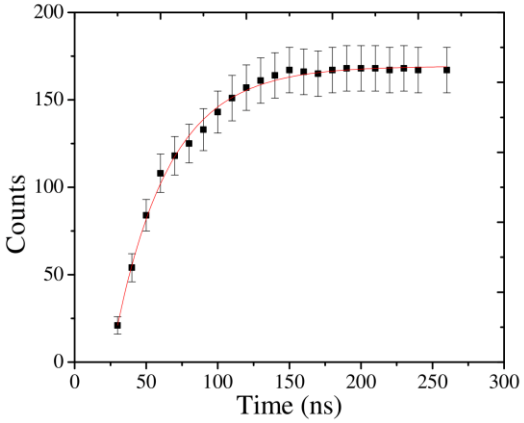

Fig. 2 Isomeric decay in ^{209}Bi observed in the present work. The time distribution of integral counts of γ rays deexciting an isomer is depicted.

The excitation mechanisms responsible for generating the excited levels established from this work will be determined by means of a systematic comparison with neighboring isotopes and through detailed, large-scale shell model calculations employing different effective interactions. It is expected that these results will complement the ones obtained by this and other groups, and thus substantially contribute towards the refinement of the effective interactions which are presently being utilized for describing nuclei in the vicinity of the doubly-magic ^{208}Pb.

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