Excited states of neutron rich $^{150}\text{Pm}$ using (p, n\(\gamma\)) reaction

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Introduction

The odd-odd lighter rare earth nuclei around the line of stability exhibit a variety of nuclear shapes and excitations, arising from the competing shape driving effects of high-j orbital [1]. The Promethium (Pm) nuclei are unique in some respect as there is no stable isotope of Pm in nature. These nuclei are synthesized in s-process either via (n,\(\gamma\)) reactions or by \(\beta\)-decay following (n,\(\gamma\)) reactions. Of the known Pm nuclei, the neutron-rich $^{147,148}\text{Pm}$ are suggested to be "branch point" nuclei in s-process path and has, therefore, drawn special attention in the recent past [2]. The next odd-odd isotope, i.e., $^{150}\text{Pm}$ [3] is known to be situated on the line of \(\beta\)-stability and is completely unknown till date; except for the half life (2.68 h) and tentative spin-parity (1\(^+\)) of the ground state. This is mainly because of the scarcity in the proper target projectile combination that can produce the excited states with a reasonable cross section. Only a few possible fusion evaporation reaction, viz., (p, \(\gamma\)); (d, 2\(\gamma\)); (\(^3\)He, d) populate the low spin states of this nucleus. In the present work, we have investigated the excited levels of $^{150}\text{Pm}$ for the first time using $^{149}\text{Nd}$ (p, \(\gamma\)) reaction with an emphasis to identify the possible excited isomers, whose presence may be crucial in s-process nucleosynthesis.

Experiment and Data Analysis

The excited states in $^{150}\text{Pm}$ were produced by using the proton beams in the energy range 8-11 MeV, obtained from the K=130 AVF cyclotron of VECC, Kolkata. The enriched (97\%) $^{150}\text{Nd}$ target on aluminized Mylar, having \(\sim 1\)mg/cm\(^2\) thickness, was prepared by electro-deposition technique. The Q-values for $^{150}\text{Nd}$ (p, \(\gamma\)) $^{150}\text{Pm}$ and $^{150}\text{Nd}$ (p, 2\(\gamma\)) $^{150}\text{Pm}$ are known to be \(-0.868(20)\) MeV and \(-6.472(4)\) MeV, respectively, from the 2003 Atomic Mass Evaluation [4]. In our experiment, both $^{149,150}\text{Pm}$ were produced at above energies with different relative yields. This has been confirmed by studying the off-beam decay of the \(\gamma\)-rays, identified to be of $^{149}\text{Sm}$ and $^{150}\text{Sm}$, produced via \(\beta\)-decay of $^{149}\text{Pm}$ (53 h) and $^{150}\text{Pm}$ (2.68 h) respectively. Two sets of known \(\gamma\)-rays have been seen, one from the 2.68 h decay of $^{150}\text{Pm}$ to the levels with spin \(\leq 2h\) in $^{150}\text{Sm}$ and the other set to levels with spin \(\geq 4h\), besides the weakly populated \(\gamma\)-rays from the 53 h $^{150}\text{Pm}$ decay. This observation suggests that there may be an isomer in $^{150}\text{Pm}$ with spin \(\geq 4\). The spin-parity of such an isomer is likely to be either 5\(^+\) or 6\(^+\), based on available orbital for odd proton/neutron and Nordheim’s rule. From the measured half life of decay \(\gamma\)-rays (cf. fig. 1), it is apparent that the latter set of \(\gamma\)-rays originate from the likely decay of an excited isomer in $^{150}\text{Pm}$ with T\(1/2\) \(\sim 3.1\) h. For in-beam singles and \(\gamma\gamma\) coincidence measurements, one segmented LEPS, one Clover HPGe and one standard (50%) HPGe detectors were placed at 135\(^0\), 90\(^0\) and 45\(^0\) respectively, around the target to identify the prompt \(\gamma\)-rays produced in the above reactions. The relative yields of some of the prompt \(\gamma\)-rays in both the residues, normalized to the intensity of 114 keV.
\(\gamma\)-ray from \(^{149}\text{Pm}\) decay, are shown in fig. 2 against the incident proton energies. It is seen that the \(\gamma\)-rays belonging to \(^{149}\text{Pm}\) show a relatively constant yield which is apparent from Q-value considerations, whereas the \(\gamma\)-rays, tentatively assigned to \(^{150}\text{Pm}\), show a decreasing trend with increasing proton energy, as expected.

From a preliminary analysis of single \(\gamma\) and \(\gamma\gamma\) coincidence data, the following \(\gamma\)-rays (tabulated in Table I) have been assigned in \(^{150}\text{Pm}\). The detailed results and the proposed level scheme of \(^{150}\text{Pm}\) would be presented.

**Table I:** List of gamma rays tentatively assigned to \(^{150}\text{Pm}\) along with their relative intensities estimated from total projection obtained with 8.5 MeV beam energy.

<table>
<thead>
<tr>
<th>(E_\gamma) (keV)</th>
<th>(I_\gamma)</th>
<th>(E_\gamma) (keV)</th>
<th>(I_\gamma)</th>
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<tbody>
<tr>
<td>59</td>
<td>54.10</td>
<td>130</td>
<td>46.63</td>
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<td>69</td>
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<td>876</td>
<td>15.30</td>
</tr>
<tr>
<td>111</td>
<td>4.83</td>
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</table>

**Fig. 1:** Decay curves for the gamma rays de-excitation the excited states of \(^{150}\text{Sm}\), produced via \(\beta^+\) decay of \(^{150}\text{Pm}\); two sets of gamma rays are observed, one with a half life of \(^{150}\text{Pm}\) ground state and the other with a longer half life.

**Fig. 2:** Plots for excitation function of the in-beam gamma rays; Gamma rays belonging to \(^{149}\text{Pm}\) shows a flat nature when normalized to 114 keV de-excitation a \(\mu\) isomer of the nucleus. The gamma rays, showing decreasing nature, are assigned to \(^{150}\text{Pm}\) produced via \((p, n\gamma)\) channel.

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**References**


