Decay of the 67-μs Isomer in ^{142}Pm *

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Excited states in ^{142}Pm are investigated via the ^{128}Te(^{19}F, 5n)^{142}Pm reaction at beam energies from 75 to 95 MeV by using techniques of in-beam γ-ray spectroscopy. Measurements of γ-ray excitation function, X–γ and γ–γ–t coincidences are performed with 10 BGO(AC)HPGe detectors. Decay of the previously known 67-μs isomer in ^{142}Pm is observed and added into the new level scheme. This isomer is definitely placed at the excitation energy of 2828.5 keV. The spin of this isomer is suggested to be 13$\hbar$ according to the measured γ-ray anisotropies.

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Since the $N = 81$ ^{142}Pm nucleus has three proton and one neutron holes in the doubly closed nucleus ^{146}Gd, its high-spin states should be formed by excitations of valence nucleons. Its low-lying energy levels can be interpreted in terms of the spherical shell model two-quasiparticle configurations with the valence neutron and proton filling the $g_{7/2}$, $d_{5/2}$, $h_{11/2}$, $s_{1/2}$ and $d_{3/2}$ orbits. Prior to this work, the high-spin level scheme of ^{142}Pm was established up to an 8 isomer with a half-life of 2 ms.[1] In addition, a 67-μs isomer has also been reported by Kenefick *et al.*[2,3] In the course of this investigation, Bhattacharya *et al.* reported a level scheme built on the 2-ms isomer via the ^{133}Cs(^{13}C, 4n)^{142}Pm reaction.[4] Though the ^{142}Pm nucleus was studied in detail, the placement of the previously known 44.0, 380.8, 426.8, 455.2, 638.6, 882.2 and 1019.4 keV γ rays de-exciting the 67-μs isomer was unknown.

The excited states in ^{142}Pm were populated via the ^{128}Te (^{19}F, 5n)^{142}Pm reaction. The ^{19}F beam was provided by the tandem accelerator at the China Institute of Atomic Energy, Beijing. The Te target was a foil of thickness of 2.2 mg/cm^2 with a 2.3 mg/cm^2 Au backing. In order to determine the optimum beam energy and to identify transitions in ^{142}Pm, the γ ray excitation functions were first measured at the beam energies of 75–95 MeV with a 5 MeV step and an optimal beam energy of 90 MeV was found, at which the ^{142}Pm yield was dominated. Then the $\gamma - -\gamma$ coincidence measurements with a coincidence time of 400 ns were carried out at this optimum energy with ten BGO(AC)HPGe detectors, having energy resolution of 2.0–2.5 keV for the 1.33 MeV line. The angle positions (and number at that angle) of these detectors were 40°(6) and 90°(4) with respect to the beam axis. All the detectors were calibrated using standard ^{152}Eu and ^{133}Ba sources. A total of 75×10^6 coincidence events were accumulated. In the data analysis a symmetric matrix with the size of 4096×4096 channels was constructed for the coincidence relationship analysis. To obtain the ADO (γ-ray angular distribution from oriented nuclei) ratios,[5] two asymmetric matrices were constructed, whose y-axes were the γ-ray energy deposited in the detectors at any angles and x-axes were the γ-ray energy deposited in the detectors at 40° and 90° respectively. The ADO ratios were defined as $R_\gamma = I_\gamma\,(40°)/I_\gamma\,(90°)$, where $I\,(40°)$ and $I\,(90°)$ were the ray intensities observed at 40° and 90° in the coincidence spectra gated on the y-axes.[5]

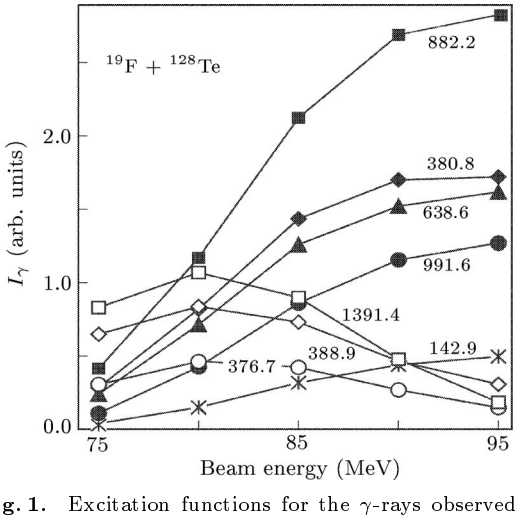


Fig. 1. Excitation functions for the γ-rays observed in the ^{19}F + ^{128}Te reaction. ^{142}Pm: 142.9 keV, 380.8 keV, 638.6 keV, 882.2 keV, 991.6 keV. ^{143}Pm: 376.7 keV, 388.9 keV, 1391.4 keV.

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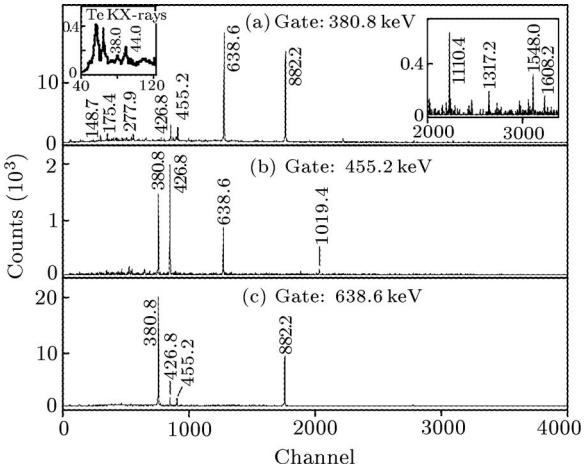


Fig. 2. The γ-ray spectra produced by gating on the 380.8, 455.2 and 638.6 keV transitions.

The measured γ-ray excitation functions (see Fig. 1), combined with Pm KX-ray coincident information (see Fig. 2(a)), confirmed the previous assignments [3,4] of the 44.0, 142.9, 221.3, 380.8, 426.8, 455.2, 638.6, 882.2, 991.6 and 1019.4 keV γ-rays to ^{142}Pm. Based on the coincidence with these strong transitions, many weak transitions have been assigned to ^{142}Pm. Gated spectrum was produced for every γ-rays assigned to ^{142}Pm. Several representative coincidence spectra are given in Fig. 2, showing the quality of the data. On the basis of the analysis of the γ-γ coincidence relationships, a level scheme for ^{142}Pm was established as shown in Fig. 3. The ordering of the transitions in the level scheme was suggested from the consideration of excitation function, relative intensity and intensity balance. In view of the large population of the 882.2 keV γ-ray (see Fig. 1), we suggest that this transition fed directly the long-lived 2-ms isomer. From the gated spectrum shown in Fig. 2(b), we find that the 455.2 keV γ-ray is coincident with the 426.8 keV γ-ray but not with the 882.2 keV γ-ray. On the other hand, gating on the 380.8 keV transition indicates the coincidence of the 44.0, 426.8, 455.2 and

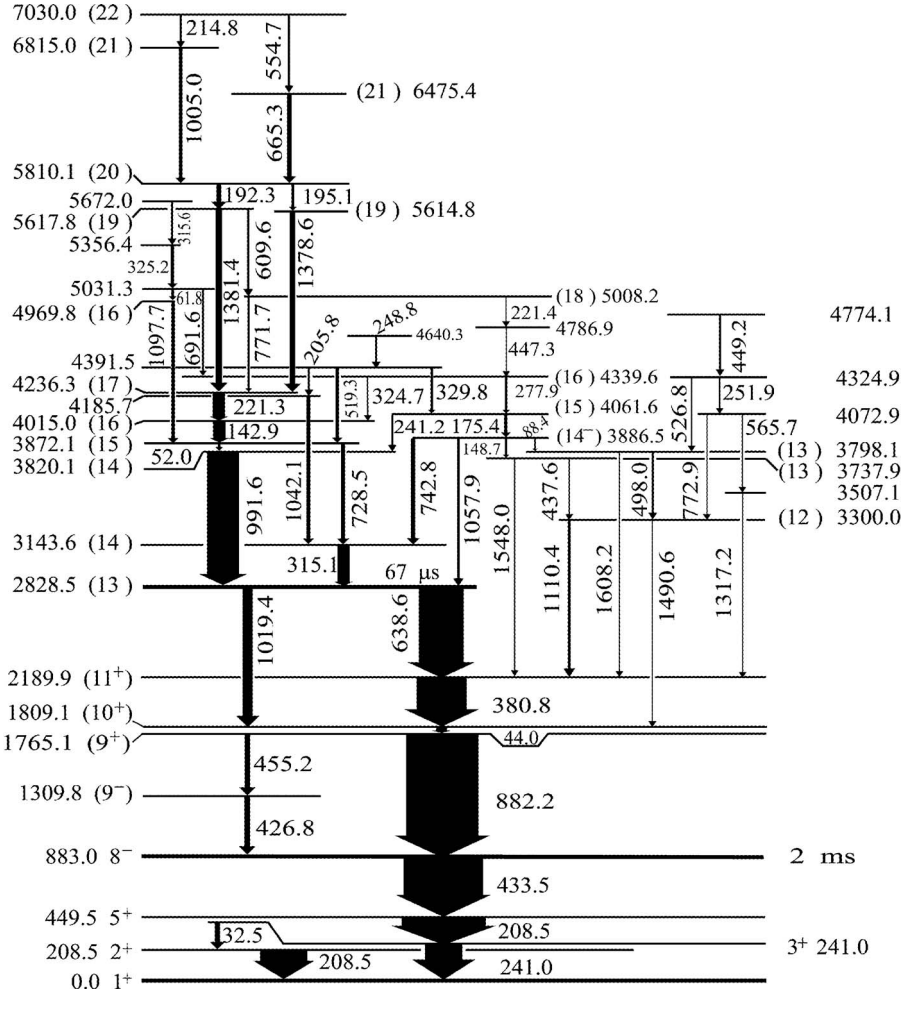


Fig. 3. Proposed level scheme for ^{142}Pm.

882.2 keV γ-rays with the 380.8 keV γ-ray (see Fig. 2(a)). The 44-keV line is a doublet (γ and K_β) for it is much stronger than the 38 keV K_α rays of Pm and we therefore could propose a 44 keV γ-ray in coincidence with the 380.8 keV transition. These coincidence relationships, together with relative intensity considerations firmly established the first four yrast levels shown in Fig. 3. It should be pointed out that the relative order of the 44.0 and 380.8 keV γ-rays was supported by the theoretical consideration (see discussion). The observed cross-over transition of 1019.4 keV necessitates the placement of the 638.6 keV γ-ray above the 2189.9 level (see Figs. 2 and 3). As a consequence, we established a level at 2828.5 keV. Since we did not observe any strong coincidence between the γ-rays below and above this level (see Fig. 2), we concluded that this state must be the 67-μs isomer observed in Refs. [2,3]. According to the measured ADO ratios of the 380.8, 426.8, 455.2 and 882.2 keV γ-rays and the comparison of the level structures above the 8^- isomers in ^{142}Pm and ^{144}Eu, we could propose spins and parities of the levels at 1309.8, 1765.1, 1809.1 and 2189.9 keV as 9^-, 9^+, 10^+, and 11^+, respectively.

The present level scheme above the 67-μs isomer is almost consistent with the previous one built up from the 2-ms isomer except for the spin assignments.[4] We also observed many new γ-rays linking the levels above and below the 67-μs isomer. The existence of the linking transitions of the 88.4, 148.7, 437.6, 498.0, 1110.4, 1490.6 and 1548.0 keV support further the placement of the γ rays above the isomer. In addition, six new γ rays, de-exciting four new levels at 3507.1, 4072.9, 4324.9 and 4774.1 keV, have been identified and are shown to the right in the level scheme of Fig. 3. The 1110.4 keV γ-ray is a typical mixed transition. Thus, the spin of the 3300.0 keV level is assigned as 12 $\hbar$. The dipole or mixed character of the 437.6 and 148.7 keV γ-rays implies spins of 13 and 14 $\hbar$ for the 3737.9 and 3886.5 keV states. The anisotropy indicates that the 1057.9 keV γ-ray might be a mixed transition and we therefore proposed a spin of 13 $\hbar$ for the isomer. This is not inconsistent with the likely $\Delta I = 0$ dipole or mixed character of the 742.8 keV transition and mixed character of the 315.1 keV transition.

The 2-ms isomer in ^{142}Pm has been assigned to be the state of the $d_{5/2}$ proton coupled to the $h_{11/2}$ neutron hole.[1] The next two-quasiparticle yrast states above the 2-ms isomer are supposed to be the members of the $\pi g_{7/2}^{-1}\nu h_{11/2}^{-1}$ and $\pi h_{11/2}\nu h_{11/2}^{-1}$ multiplets. Such two-quasiparticle multiplets should be easy to observe by using (HI, xn) reactions. Indeed, the first 9^- state was identified in ^{144}Eu at 1338 keV excitation and was assigned to be the $\pi g_{7/2}^{-1}h_{11/2}^{-1}$ two-hole state.[5] In view of this and the similar excitation energy of the 1309.8 keV level in ^{142}Pm, we could propose the same configuration for the 1309.8 keV level. The members of the $\pi h_{11/2}\nu h_{11/2}^{-1}$ multiplet have also been observed in ^{144}Eu, where the 10^+ state lies very close to 9^+ and the 11^+ is much higher.[5] This is the case in ^{142}Pm. Thus, the levels at 1765.1, 1809.1 and 2189.1 keV in ^{142}Pm should be the 9^+, 10^+ and 11^+ states of the $\pi h_{11/2}\nu h_{11/2}^{-1}$ multiplet.

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