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Decay of the very neutron-deficient isotope ^{131}Pm[*]

Z.G. Gan, Z. Qin, J.S. Guo, L.J. Shi, H.Y. Liu, T.R. Guo, X.G. Lei, R.C. Ma, W.X. Huang, S.G. Yuan, X.Q. Zhang, G.M. Jin

Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, 730000, P.R. China

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Abstract. The decay of ^{131}Pm has been investigated by means of γ-ray spectroscopy. The ^{131}Pm nuclei were produced by fusion-evaporation reaction of ^{106}Cd(^{32}S,3p4n) at the beam energy of 170 MeV. A helium-jet technique and a tape transport system were used to collect the activities and transfer them to a detecting position for X and γ rays measurement. Two γ rays of 185.0 and 220.0 keV were unambiguously identified to follow the β^+ decay of ^{131}Pm by results of X-γ and γ-γ coincidence. A growth-decay feature of the decay curve for 87.8 keV γ-ray of ^{131}Nd confirmed the production of ^{131}Pm nuclei. The half-life of ^{131}Pm was measured to be 6.3±0.8 s. A partial decay scheme of ^{131}Pm is proposed on the basis of X-γ and γ - γ coincidence data in this experiment and the known structure information deduced from in-beam experiments of the daughter nucleus ^{131}Nd.

PACS. 27.60.+j $90 \leq A \leq 149$ – 21.10.Tg Lifetimes – 29.30.Kv X- and γ-ray spectroscopy

1 Introduction

For the past twenty years studies of neutron-deficient nuclei in Z>50, N<82 region have revealed many interesting features on both collective motion and particle excitation[1,2,3]. High-spin states level structure information of these nuclei was obtained from in-beam γ spectroscopy experiments. However, there is less information about low-energy, low-spin states for these nuclei. This information is expected to emerge from the investigation of β and γ decay spectroscopy.

The neutron-deficient odd-A promethium nuclei such as ^{133,135,137}Pm have been studied and the information of their shape transition has been obtained. These nuclei decay predominantly by β-decay from the $11/2^-$ ground state of Pm isotope to $11/2^-$ level of corresponding daughter neodymium isotope[1,2,3,4]. For more neutron-deficient nuclide ^{131}Pm, however, no information on its decay properties has been reported up to now. A. N. James *et al.* [5] reported that three strong prompt γ-rays for ^{131}Pm were observed in an in-beam spectroscopy experiment. However, they did not report the half-life and decay γ-rays of ^{131}Pm. Structure information deduced from in-beam spectroscopy for ^{131}Nd, which is the daughter nuclide of ^{131}Pm, has been reported in [6].

In the present work, the decay properties of ^{131}Pm are reported. Two γ-rays are assigned to the decay of ^{131}Pm. Its half-life is determined. From the γ energy, half-life and X-γ coincidence, systematical trends of neighboring odd-A promethium nuclei and the data of the level structure of the known daughter nuclide ^{131}Nd, a preliminary partial decay scheme of ^{131}Pm is proposed.

2 Experimental procedure

The ^{131}Pm nuclei were produced by the reaction of ^{106}Cd(^{32}S, 3p4n) with beams of ^{32}S ions at the beam energy of 170 MeV delivered from SFC (Section Focus Cyclotron) of HIRFL (Heavy Ion Research Facility Lanzhou). The optimum bombarding energy for yield of ^{131}Pm residual nuclide was estimated on the basis of the excitation function calculated by the computer code ALICE [7]. The target of ^{106}Cd was enriched to 85% and rolled as a metal foil with a thickness of 1.8 mg/cm^2. The experimental equipment employed include a helium-jet target chamber and a capillary transport system as well as a rapid tape transport system. Reaction products recoiled out from the target foil were stopped in helium gas loaded with NaCl aerosols produced by sublimation from the surface of NaCl powder at 650°C. The products attached to the aerosols were swept out of the target chamber with helium gas passing through a capillary (1.8 mm i.d. and 10 m length) to the low background area where the products were implanted onto an aluminum-coated nylon tape. After collecting for a preset time period, the collected radioactivities were transported over a distance of ~1 m to a counting position using a rapid tape transport system for the purpose of reducing the background originated from

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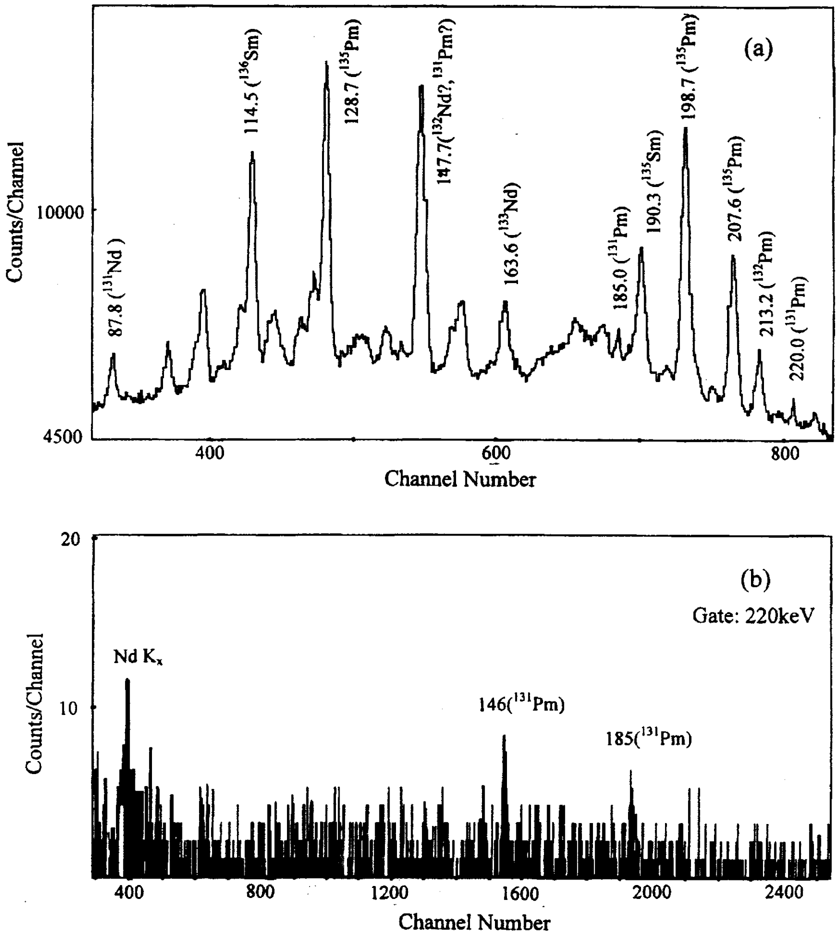

Fig. 1. (a)The partial γ-ray singles spectrum measured by using the HPGe detector in the ^{32}S+^{106}Cd reaction with 170 MeV bombarding energy. (b) The coincidence spectrum measured by using the X-ray detector gated on the 220.0 keV γ-ray. The energies of the marked peaks are in keV

γ-rays emitted by long lived activities. The X, γ singles and γ-X,γ-γ coincidence measurements were performed by a planar HPGe detector and two GMX HPGe detectors. The energy scale of the spectrometers was calibrated by ^{133}Ba, ^{60}Co and ^{152}Eu reference sources for X and γ-rays. Both collecting time and counting time of the tape transport system were 40 s. The coincidence data were recorded event by event in a magnetic tape.

3 Results and discussion

A typical singles spectrum of γ rays and a coincidence spectrum gated on the 220.0 keV γ-ray are shown in Fig. 1(a) and (b) respectively. The γ-rays with energies of 87.8, 185.0 and 220.0 keV are clearly observed in the Fig. 1(a). The 87.8 keV γ-ray was found to be in coincidence with the Pr X-rays in the present experiment. This γ-ray has been assigned to the decay of ^{131}Nd by [6,8]. Moreover, the decay curve of this γ-ray has a growth-decay behavior as shown in Fig. 2. This feature indicates that the ^{131}Nd nuclide is not directly produced in the nuclear reaction but from the corresponding parent nuclide. A growth half-life of 6.7±2.5 s and a decay half-life of 26.6±1.7 s were extracted from the decay curve of the 87.8 keV γ-ray of Fig. 2 using a computer code for analyzing the decay of a radioactive series. The latter is in good agreement with the half-life 27 s of the known ^{131}Nd [6], and the former should be assigned to the β^+/EC decay of the parent nuclide ^{131}Pm of ^{131}Nd. Meanwhile, two γ-rays of 185.0 and 220.0 keV are observed to be in coincidence with Nd X-rays. It demonstrates that these γ-rays arise following the β^+/EC decay of promethium isotopes. The half-lives of 185.0 and 220.0 keV γ-rays are measured to be 6.2±1.0 s and 6.4±1.4 s, respectively, as also shown in Fig. 2. The half-lives of these two γ-rays are consistent with the growth half-life of 6.7±2.5 s obtained from 87.8 keV ray within experimental uncertainty. An analysis and a comparison with the low-lying state level schemes of the known neodymium nuclei for 185.0 and 220.0 keV γ-rays show that these two γ-rays most probably arise from the level transition of ^{131}Nd following ^{131}Pm β^+/EC decay. Therefore, 185.0 and 220.0 keV γ-rays could be assigned to the decay of ^{131}Pm. According to all of the above evidence and analysis, the half-life of ^{131}Pm is determined to be 6.3±0.8 s from weighted mean of 6.2±1.0 s for 185.0 keV, 6.4±1.4 s for 220.0 keV and 6.7±2.5 s for the growth-in half-life of the 87.8 keV transition. This half-life value is consistent with the predicted value by Gross theory [9].

On the basis of the above experimental results of X-γ and γ-γ coincidence measurements and the low-lying level structure of ^{131}Nd obtained from in-beam γ-spectroscopy [6], a partial decay scheme of ^{131}Pm is tentatively pro-

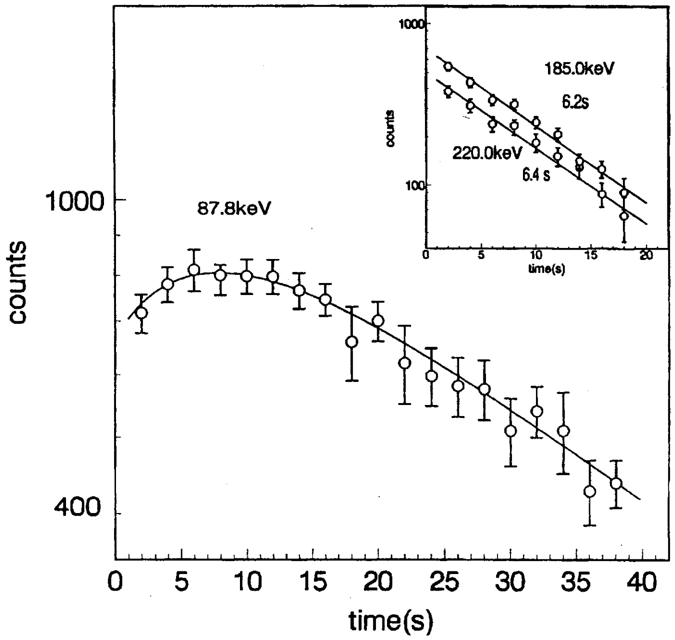

Fig. 2. The growth-decay curve of the 87.8 keV γ-ray. The decay curves and half-lives of the 185.0 keV and 220.0 keV γ-rays are shown in upper right of the figure

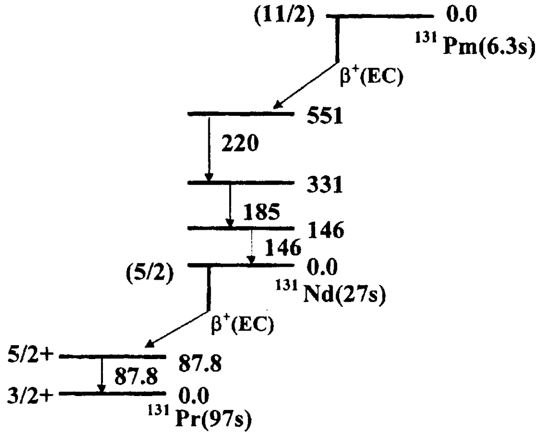

Fig. 3. The proposed partial decay scheme of ^{131}Pm

posed as shown in Fig. 3. According to the systematics of the neighboring odd-A promethium nuclei, the spin and parity of the ground state for ^{131}Pm is assumed to be $11/2^-$. A γ-ray with energy of 146.0 keV was found to be in the coincidence with the characteristic X ray of neodymium. Meanwhile, γ-γ coincidence measurement indicates that 146.0 and 185.0 keV γ-rays are coincident with 220.0 keV γ-ray as shown in Fig. 1(b). This fact demonstrates that the 146.0 keV γ-ray also arises from the decay of ^{131}Pm. Although half-life of the 146.0 keV γ-ray was not measured in the present work due to a big disturbance by a strong γ-peak with energy of 147.7 keV in the singles spectrum , the position of this 146.0 keV γ-ray still could be determined in the proposed decay scheme of ^{131}Pm based on its coincidence relation with 185.0, 220.0 keV γ-rays and K X-rays of Nd as mentioned above. It is a transition from the 146 keV level to the ground state (5/2) of ^{131}Nd based on the known in-beam low lying level scheme of ^{131}Nd reported in [6]. According [6] two γ-rays of 331.0 and 405.0 keV were expected (they are the transitions from 331 keV level to 5/2 ground state and from 551 keV level to 146 keV level, respectively, in the known level scheme of ^{131}Nd deduced from in beam measurements). Unfortunately, we did not observe these two γ-rays in this experiment. Moreover, the half-life of ^{131}Pm measured in this work is very similar to that of ^{132}Pm. One should notice that, however, ^{132}Pm is a known β-delayed proton precursor. Its decay γ-rays have been compiled in [10]. The three γ-rays of 185.0, 220.0 and 146.0 keV measured in the present work have not been observed in the known decay γ-rays of ^{132}Pm, and no 87.8 keV γ-ray has been observed in its daughter ^{132} Nd. Therefore, this fact excludes the possibility that the measured three γ-rays of 185.0, 220.0 and 146.0 keV originate from ^{132}Pm.

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