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Short note

(EC+β^+) decay of ^{130}Pm and ^{128}Pr

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Abstract. ^{130}Pm and ^{128}Pr were produced by irradiation of ^{96}Ru with ^{36}Ar, and studied using a He-jet recoil tape transport system. Based on X-γ and γ-γ coincidence measurements, the (EC+β^+) decay scheme of ^{130}Pm was proposed for the first time and the (EC+β^+) decay scheme of ^{128}Pr was revised.

PACS. 23.40.-s β decay; double β decay; electron and muon capture – 23.20.Lv Gamma transitions and level energies – 21.60.Cs Shell model

The β-delayed protons from ^{130}Pm and ^{128}Pr decays were measured with half-lives 2.2(6)s and 3.2(5)s [1], respectively. The level schemes of their daughter nuclei ^{130}Nd and ^{128}Ce obtained by means of in-beam gamma study have been reported [2,3]. However, the (EC+β^+) decay scheme of ^{130}Pm has not been proposed so far. Although a simple (EC+β^+) decay scheme of ^{128}Pr with six observed γ rays was published in 1988 [4], some of the low-lying states of ^{128}Ce in the decay scheme are not consistent with the level scheme of ^{128}Ce [3]. Therefore, the revision of the (EC+β^+) decay scheme of ^{128}Pr is necessary.

The experiment was carried out at the SFC accelerator of IMP, Lanzhou, China. A 220-MeV-$^{36}Ar^{11+}$ beam from the cyclotron entered a target chamber filled with 1-atm. helium, passing through a 1.94mg/cm^2 Havar window and 7-cm helium gas, and finally bombarded a 2.8mg/cm^2 ^{96}Ru target (94% enriched) with a 0.3mg/cm^2 aluminum backing after losing ∼40MeV in the window and the helium gas. The beam intensity was about 0.5eμA. We used a He-jet in combination with a tape-transport system to move the radioactivity into a shielded counting room. $PbCl_2$ was used as aerosol at 430^{o}C. The γ rays from the reaction products were measured up to 2.0MeV using two coaxial HpGe(GMX) detectors. A HpGe planar detector was used for X-ray measurements. The γ-γ-t or X-γ-t coincidence events were collected event-by-event on magnetic tapes. The observed intense γ lines of ^{130}Pm (^{128}Pr) were assigned by the coincidence measurements with Nd-K_αX(Ce-K_αX) ray as well as based on the level scheme of ^{130}Nd [2] (^{128}Ce[3]). The observed weak γ lines of ^{130}Pm (^{128}Pr) were assigned by the coincidence measurements with the X ray and with already assigned intense γ rays of ^{130}Pm (^{128}Pr).

Table 1. The γ-transitions and their coincidence relationships in the decay of ^{130} Pm

E_γ (keV)	I_γ	Coincident relations
158.9(2)	100*	326.3, 454.2, 547.2, 787.4, 793.4, 1026.2
326.3(3)	76(3)	158.9, 454.2, 547.2
454.2 (3)	44(3)	158.9, 326.3
547.2(4)	13(5)	158.9, 326.3
787.4(4)	7(6)	158.9
793.4(4)	7(5)	158.9
1062.2(4)	9(8)	158.9

* Including correction of internal conversion electron

^{130}Pm: From the time spectra of intense γ lines of ^{130}Pm, the weighted average half-life value of ^{130}Pm was determined to be 2.6(2)s, which is 0.4 s longer than previous result [1]. The observed γ-ray intensities mainly from γ-singles measurements and the γ-γ coincidence relations in ^{130}Pm decay are listed in Table 1, which leads us to suggest the decay scheme shown in Fig. 1. The Q_{EC}value is a systematic prediction given by Audi et al. [5]. In Fig. 1 besides the known 2^+,4^+ and 6^+ levels of the ground band [2], four new levels of ^{130}Nd were found at the energies of 946.3, 952.3, 1032.4 and 1185.1 keV, respectively. According to the upper limits of the side feeding to each level ($I^{u.l}_{EC+\beta^+}$) by (EC+β^+) decay in Fig. 1 the lower limits of the logft values (log$ft^{l.l.}$) shown in the right part of

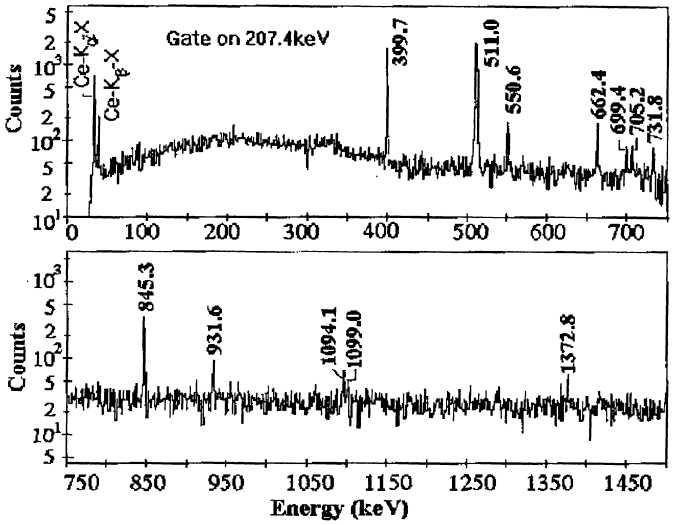

Fig. 1. Proposed decay scheme of ^{130}Pm

Fig.1 were calculated with the table of Gove and Martin [6]. Based on the selection rule of β decay, a possible assignment of the ground-state spin and parity of ^{130}Pm is 5^+. However, if any intense γ ray with the energy higher than 2.0MeV deexcited to 485.2-keV 4^+ state or 939.4-keV 6^+ state was missing, 6^+ or 4^+ could also be assigned to the ground state of ^{130}Pm. The assignment of 6^+ is consistent with the prediction given by macroscopic-microscopic model of Möller et al. [7], which is composed of a $\nu 7/2[523]$ and a $\pi 5/2[532]$ quasi-particles.

^{128}Pr: The weighted average half-life of ^{128}Pr was determined to be 2.8(1)s, which is consistent with previous results [1,4] within experimental errors. The observed γ-ray intensities and the γ-γ coincidence relations in ^{128}Pr decay are listed in Table 2. The proposed (EC+β^+) decay scheme of ^{128}Pr is shown in Fig. 2. The Q_{EC}value is a sysmatic prediction given by Audi et al. [5]. In the low-energy

Table 2. The γ-transitions and their coincidence relationships in the decay of ^{128}Pr

E_γ (keV)	I_γ	Coincident relations
207.4(2)	100*	399.7, 550.6, 662.4, 699.4, 705.2, 731.8, 845.3, 931.6, 1094.1, 1099.0, 1372.8
399.7(3)	26(1)	207.4, 550.6, 699.4, 705.2, 731.8, 1094.1, 1372.8
550.6(3)	3.4(3)	207.4, 399.7, 731.8
662.4(4)	4.8(2)	207.4
669.4(4)	1.1(5)	207.4, 399.7
705.2(4)	1.5(4)	207.4, 399.7
731.8(4)	1.8(4)	207.4, 399.7, 550.6
845.3(3)	11.2(2)	207.4
931.6(4)	4.0(3)	207.4
1094.1(4)	1.4(4)	207.4, 399.7
1099.0(4)	2.9(4)	207.4
1372.8(4)	2.4(4)	207.4, 399.7

* Including correction of internal conversion electron

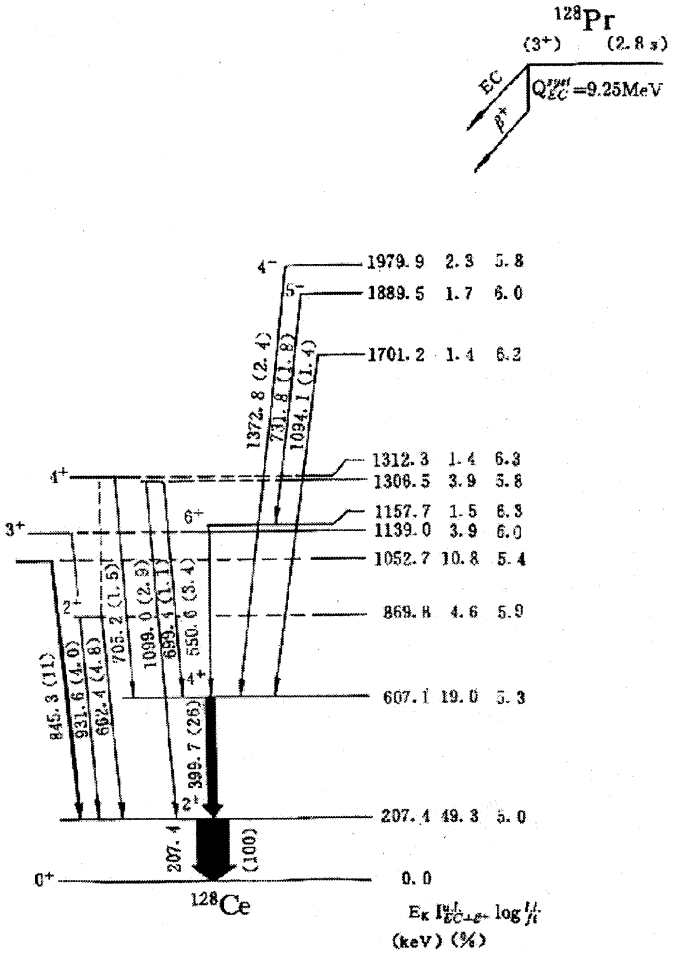

Fig. 2. Proposed decay scheme of ^{128}Pr

region of ^{128}Ce, the bandheads of band 1, 2, 6 and 8 in reference [3] were found besides the three lowest-energy members of the yrast band. A new low-lying state with the energy of 1052.7keV deexcited to the lowest-energy 2^+ state via an intense 845.3-keV γ ray and another new one with the energy of 1306.5keV were observed. However, we could not see any indication of 592-, 799- and 873-keV γ rays reported in reference [4]. For an example,the 592- and 799-keV γ rays could not be seen in the coincident γ spectrum gated on 207.4-keV γ ray shown in Fig. 3. Based on the selection rule of β decay, we are not able to assign the ground-state spin and parity of ^{128}Pr to 5^+, which as predicted by Möller et al. [7] is composed of a $\nu 7/2[523]$ and a $\pi 3/2[541]$ quasi-particles. A possible assignment of the ground-state spin and parity of ^{128}Pr could be 3^+ because the lower limits of logft value to the 2^+, 3^+, or 607.1-keV 4^+ states in ^{128}Ce are less than 6.00. In a projected shell model [8] calculation,by taking large deformations ε_2=0.370 and ε_4=0.0228 and slightly weak pairing parameters G_1=19.24MeV and G_2=13.86MeV, the ground-state spin and parity of ^{128}Pr was calculated to be 3^+ composed of a $\nu 1/2[541]$ and a $\pi 5/2[532]$ quasi-particles.

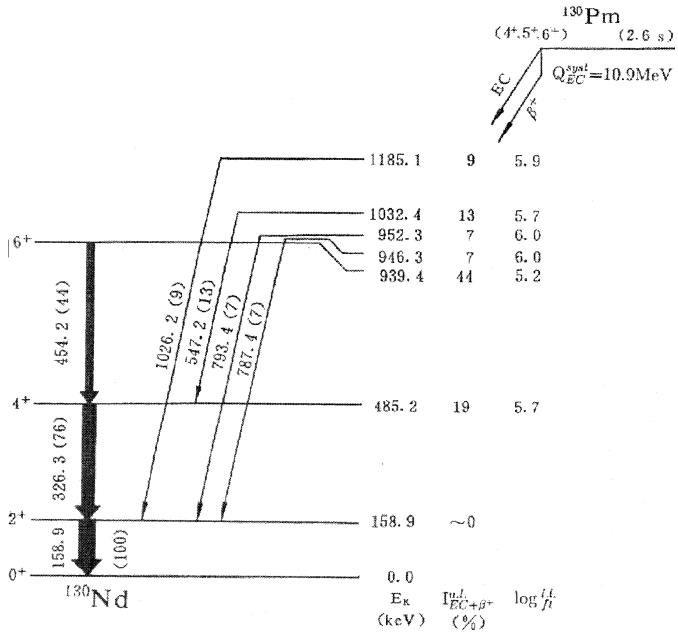

Fig. 3. Gamma-ray spectrum gated by 207.4-keV γ ray following the decay of ^{128}Pr. The coincident peaks assigned to ^{128}Pr are marked with their energies in keV

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