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Short note

β-delayed Proton Decay of ^{89}Ru

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Abstract. A β-delayed proton activity with a half-life of 1.2 ± 0.2 s was assigned to ^{89}Ru on the basis of a p-γ(X) coincidence measurement in the reaction of ^{58}Ni (^{36}Ar, 2p3n) using a He-jet tape transport system. The measured delayed-proton spectrum of ^{89}Ru and relative proton branching ratios to the low-lying states in ^{88}Mo were compared with statistical model calculations.

PACS. 23.40.-s β decay; double β decay; electron and muon capture – 21.10.Tg Lifetimes – 27.50.+e $59 \leq A \leq 89$

^{89}Ru belongs to the T_z=1/2 series of precursors and lies in the region of particular interest due to the rapidly changing deformation [1]. It was firstly identified by charge number (Z) and mass number (M) recognition [1], but no any other nuclear information about ^{89}Ru was given until now. In this work a "p-γ" coincidence method [2,3] was used to identify the precursor, and a half-life of 1.1 ± 0.2 s was assigned to ^{89}Ru decay. In general, in the EC/β^+ decay of an even Z and odd N precursor, the excited states above the proton binding energy in the odd (Z-1) and even (N+1) "emitter" are populated, and then could deexcite via proton emission to the low-lying excited states and ground state in the even (Z–2)-even (N+1) "daughter" nucleus. Most of the low-lying excited states would deexcite to the 0^+ ground state via the lowest energy $2^+ \rightarrow 0^+$ transition. Therefore the $2^+ \rightarrow 0^+ \gamma$ ray transition in a particular "daughter" nucleus coincident with β-delayed protons, as we called "p-γ" coincidence, could be used to identify its precursor unambiguously instead of using an ISOL.

The experiment was carried out at the SFC cyclotron of HIRFL (Heavy Ion Research Facility in Lanzhou). An enriched isotope ^{58}Ni (enrichment 99%) target with a thickness of 3.0 mg/cm^2 was bombarded by a 220 MeV ^{36}Ar^{11+} beam with a beam intensity of 0.3 eμA. The effective beam energy on target was about 188MeV due to the energy losses in the entrance window (1.94mg/cm^2 Havar foil) and in helium gas. A He jet in combination with a fast tape-transport system was used to move the radioactivity into a shielded location for p-γ(X)-t coincidence measurements. Two 570mm$^2\times$350 μm totally depleted silicon surface barrier detectors were used for proton measurements, and face to face located on opposite two sides of the movable tape. This detector system has a solid angle of $75 \times 4\pi$ sr and its energy resolution was 80 keV (for 5.486MeV ^{241}Am Alphas). Behind each Si(Au) detector a coaxial HpGe(GMX type) detector was used for γ(X) measurements. The collection time, waiting time, tape transport time and accumulation time were 2.1s, 0.1s, 0.3s and 2.0s, respectively.

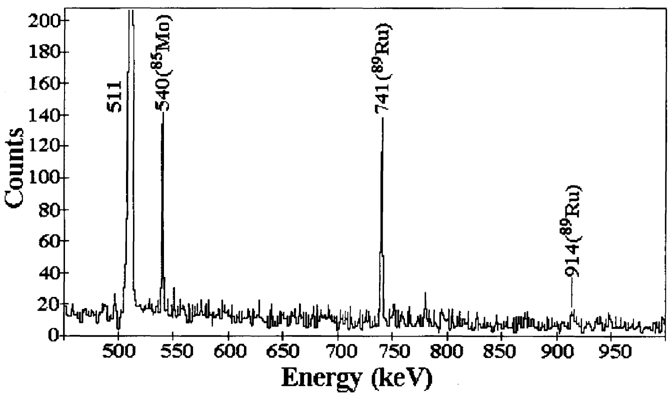

Fig. 1. The γ(X) spectrum gated on 2.2 to 5.0 MeV protons in ^{36}Ar+^{58}Ni reaction, where 540-keV γ ray was arised from the deexcitation of low-lying states of ^{84}Zr produced in β-delayed proton decay of ^{85}Mo [12], and the 741-keV and small 914-keV γ peaks, corresponding to the $2^+ \rightarrow 0^+$ and $4^+ \rightarrow 2^+$ transitions in ^{88}Mo, respectively, were assigned to the precursor ^{89}Ru

The γ(X)-spectrum gated on 2.2- to 5.0MeV protons is shown in Fig. 1. The proton spectrum gated by the 741-keV γ ray and the time spectrum of the 741-keV γ ray gated by protons are shown in Fig. 2(a) and Fig. 2(b), respectively. The 741-keV gamma transition was attributed

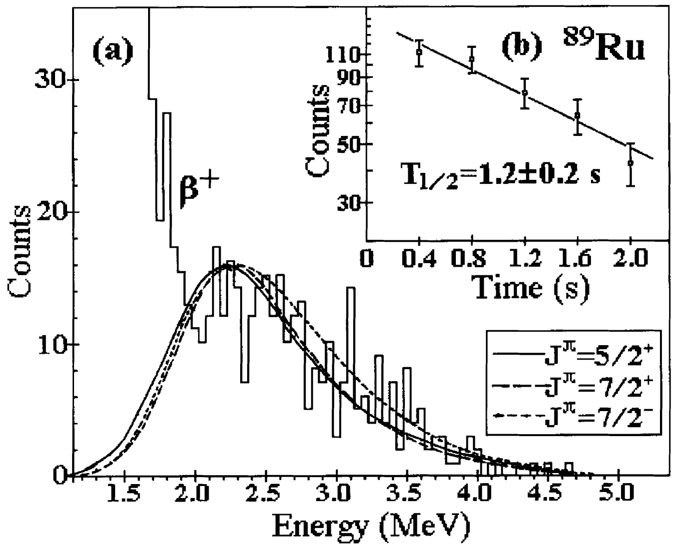

Fig. 2. The measured proton spectrum gated by the 741-keV γ ray (histogram) compared with calculated spectra assuming the spin and parity of ^{89}Ru I^{π}=7/2 (dashed line), $7/2^-$ (dotted line) and $5/2^+$ (full line), respectively

to the deexcitation of the lowest energy 2^+ state to the 0^+ ground state in ^{88}Mo produced from the β-delayed proton decay of ^{89}Ru based on the following arguments: (1) 741keV is the energy of the $2^+ \rightarrow 0^+$ transition in ^{88}Mo[4]; (2) In the γ(X)-ray spectrum gated on both 2.5- to 5.0-MeV protons and 741-keV γ ray, only one peak with four counts was found, and located around 18.3 keV, the energy of the Tc-K_α X ray. This implies that the 741-keV γ-ray transition is related to the decay of an EC/β^+-emitting ruthenium isotope; (3) In addition, no any other β-delayed proton precursor with a short half-life produced in this reaction decays via 741-keV γ transition. From Fig.2(b) the experimental half-life of ^{89}Ru was extracted to be 1.2±0.2 s, which is slightly longer than the theoretical values: 0.89s (Hilf), 0.72s (Groote) and 0.43s (Möller) predicted by the microscopic model of Hirsch et al. [5], but shorter than 3.8 s calculated by using gross theory [6].

A small peak at an energy of 914 keV in the proton-coincident γ spectrum (Fig. 1) was also assigned to the precursor ^{89}Ru because it agrees in energy with the $4^+ \rightarrow 2^+$transition in ^{88}Mo [4]. The relative proton branching ratios to 2^+ and 4^+ states in ^{88}Mo were estimated to be 100: 8(4). In order to compare the experimental results with theoretical prediction a revised statistical model calculation [7] was made by using a structureless Gamow-Teller β-strength function obtained from gross theory [8] and a level density under the backshifted Fermi gas prescription [9]. The Q_{EC} and B_p value used in the calculations are taken from [10]. Reasonable assignment of the spin and parity of ^{89}Ru could be $5/2^+$,$7/2^+$ or $7/2^-$which give final-state proton branching ratios of 69.9% (0^+), 29.3% (2^+), 0.8% (4^+); 51.1% (0^+), 46.0% (2^+), 3.0% (4^+); and 48.8% (0^+), 47.7% (2^+), 3.6% (4^+) respectively, and well reproduced the experimental proton spectrum. The above preliminary spin-parity assignment of ^{89}Ru is neither contradict to $7/2^+$ of the systematics of N=45 isotopes nor to the prediction of a spin of $5/2^+$ given by Möller et al. [11], but disagrees with $9/2^+$ expected by Audi et al.[10].

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