The Decay of a Tz = -1/2 Mirror Nucleus 57Cu

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I. 5 The Decay of a $T_z = -1/2$ Mirror Nucleus ^{57}Cu

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The neutron-deficient mirror nuclei of the $f_{7/2}$-$p_{3/2}$ shell region are difficult to observe because of their small production cross sections and their short half-lives.[1-3] In order to study such a nucleus far from the beta-stability line, we developed a high-speed TArget ROtation system (TARO) mentioned before.[4] Using this system, we studied the decay of a new short-lived nucleus ^{57}Cu, which is very interesting because it consists of the ^{56}Ni core and one proton in the $p_{3/2}$ shell. From this experiment, the half-life and $E_{\beta^+}^{max}$ of the decay of ^{57}Cu were obtained.

^{57}Cu was produced in the (p,2n) reaction on ^{58}Ni targets of 2-3 mg/cm^2 enriched to 99.76 %. The proton beam current and energy were typically 0.2-0.3 μA and 25-34 MeV, respectively. Sixteen ^{58}Ni targets were distributed on the rotating plate[4] in order to reduce the accumulation of long-lived isotopes. The proton beam was pulsed to irradiate these targets sequentially; the irradiated target was rotated in 60 ms to the shielded detector position and was measured.[4]

The γ-rays and positrons were measured in two-parameter (energy and time) list modes with a 96 cm^3 coaxial Ge(HP) and a 490 mm^2 × 10 mm planer Ge(HP) detectors, respectively. We collected typically 10^7 events for positrons.

In the γ-ray energy spectrum we discovered the γ-ray of 1112 keV decaying with a half-life of $T_{1/2} = 233 \pm 16$ ms, which we assigned to depopulate the second-excited state ($I^\pi = 1/2^-$) of ^{57}Ni[5] fed from the decay of ^{57}Cu. The γ-ray's energy was obtained to be 1111.7 ± 0.5 keV. Figure 1 shows a γ-ray spectrum and the decay of the 1111.7 keV γ-ray. This half-life value is consistent with a value of 0.2 s predicted from the gross theory of β-decay.[6] No other γ-rays from ^{57}Cu were found.

As an aid in the identification of ^{57}Cu, the γ-ray yield curves were compared with theoretical excitation functions calculated by ALICE.[7] The experimental curves were in good agreement with the theoretical ones as shown in Fig. 2.

The observed positron spectrum included the backgrounds due to ^{54}Co($T_{1/2}$ = 196 ms, $E_{\beta^+}^{max}$ = 7.2 MeV[5]) and ^{58}Cu($T_{1/2}$ = 3.2 s, $E_{\beta^+}^{max}$ = 7.5 MeV[5]). The $E_{\beta^+}^{max}$ of ^{57}Cu was predicted to be closed to $E_{\beta^+}^{max}$ of these background.[8] Therefore, we determined $E_{\beta^+}^{max}$ of ^{57}Cu using a "time-filtering" analysis. By taking advantage of the difference in half-life, we subtracted the background due to ^{58}Cu and others from the raw positron spectrum as shown in Fig. 3. This "time-filtered" spectrum should be composed of positrons from short-lived ($T_{1/2} \simeq 200$ ms) nuclei. This spectrum showed a $E_{\beta^+}^{max}$ larger than that of ^{54}Co measured using the

^{54}Fe(p,n)^{54}Co reaction. We deduced $E^{max}_{\beta^+}(^{57}Cu)$ by the Kurie-plot analysis of the part of the "time-filtered" spectrum having $E_{\beta^+} > E^{max}_{\beta^+}(^{54}Co)$ on the basis of the method of Rehfield.[9] Thus we obtained $E^{max}_{\beta^+}(^{57}Cu) = 7.72 \pm 0.13$ MeV. The branching ratio to the 1111.7 keV excited state of ^{57}Ni was found to be 3.7 ± 1.7 % from γ- and positron spectra.

Using the f-value from Ref. 10), the logft value for the ground state decay of ^{57}Cu was obtained to be logft = 3.71 ± 0.05, and the GT matrix element was obtained[11] to be $\langle\sigma\tau\rangle_{exp} = 0.37 \pm 0.11$. This value indicates a large reduction in comparison with the $p_{3/2}$ pure single-particle estimate $\langle\sigma\tau\rangle_{s.p.} = 1.291$.

The measured mass excess of ^{57}Cu is compared with several mass predictions[12] in Table 1. Agreement between experiment and theory is fairly good except the value estimated by Meyers with semiempirical droplet model. The Coulomb displacement energy was found to be $\Delta E_C = 9.524 \pm 0.13$ MeV from the present value. This value is in good agreement with the estimated value using the phenomenological formulae of Jänecke.[13]

References

1) Hornshøj P., Lokind J. and Rud N., Phys. Lett. <u>116B</u> No. 1 (1981) 4.
2) Arai Y., Fujioka M., Tanaka E., Shinozuka T., Miyatake H., Yoshii M. and Ishimatsu T., Phys. Lett. 104B No. 3 (1981) 186.
3) Sherrill B., Beard K., Benenson W., Brown B. A., Kashy E., Ormand W. E., Nann H., Kehayias J. J., Bacher A. D. and Ward T. E., Phys. Rev. C 28 No. 4 (1983) 1712.
4) Miyatake H., Shinozuka T., Yoshii M., Hama H., Kamiya T. and Fujioka M., CYRIC Ann. Rept. (1982) 54.
5) Table of Isotopes, 7th ed., ed. by Lederer C. M. and Shirley V. S. (Wiley, Interscience, New York 1978).
6) Takahashi K., Yamada M. and Kondoh T., Atom. Data and Nucl. Data Tables 12 (1973) 101.
7) Blann M., OVERLAID ALICE, Rep. COO-3494-29 (1979).
8) Wapstra A. H. and Bos K., Atom. Data and Nucl. Data Tables 19 (1975) 175.
9) Rehfield D. M., Moore R. B. and Hetherington D., Nucl. Instr. and Meth. 178 (1980) 565.
10) Wilkinson D. H. and Macefield B. E. F., Nucl. Phys. A155 (1970) 582.
11) Wilkinson D. H., Nucl. Phys. A209 (1973) 470.
12) Maripuu K. and Way K., Special ed., Atom. Data and Nucl. Data Tables 17 (1976) 494.
13) Jänecke J., Isospin in Nuclear Physics, ed. by Wilkinson D. H. (North-Holland, Amsterdam, 1968) 257.

Table 1. Comparison of mass predictions with the experimental value.

Mass prediction[12)]	Mass excess (MeV)
Meyers	-51.47
Groote-Hilf-Takahashi	-47.73
Seeger-Howard	-47.7
Liran-Zeldes	-47.20
Beiner-Lombard-Mas	-44.9
Jänecke-Garvey-Kelson	-47.43
Experimental value	-47.36 (13)

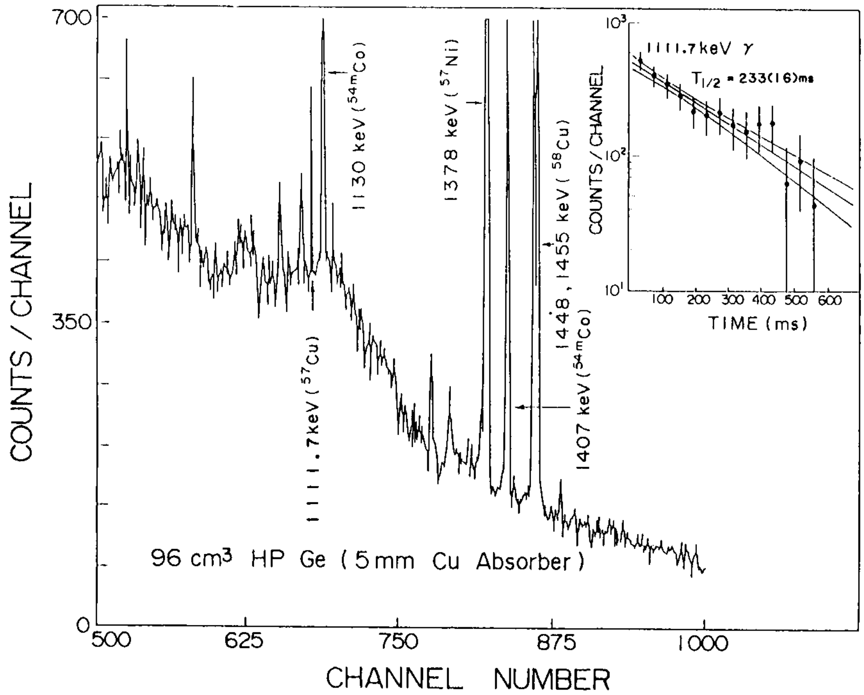

Fig. 1. The γ-ray spectrum and the half-life of 1111.7 keV γ-rays assigned to the decay of ^{57}Cu

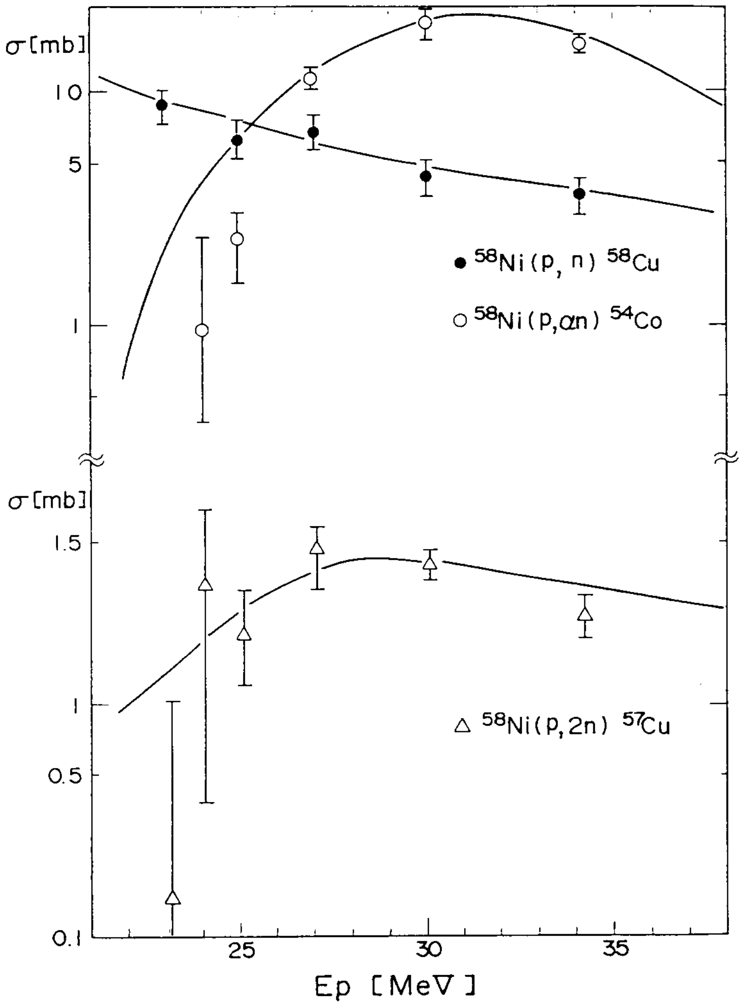

Fig. 2. Yield curves for ^{57}Cu, ^{54}Co and ^{58}Cu in the (p,2n), (p,αn) and (p,n) reactions, respectively. The solid curves are theoretical ones calculated by the cross section code ALICE.$^{7)}$ The experimental data are normalized at the bombarding energy of 30 MeV.

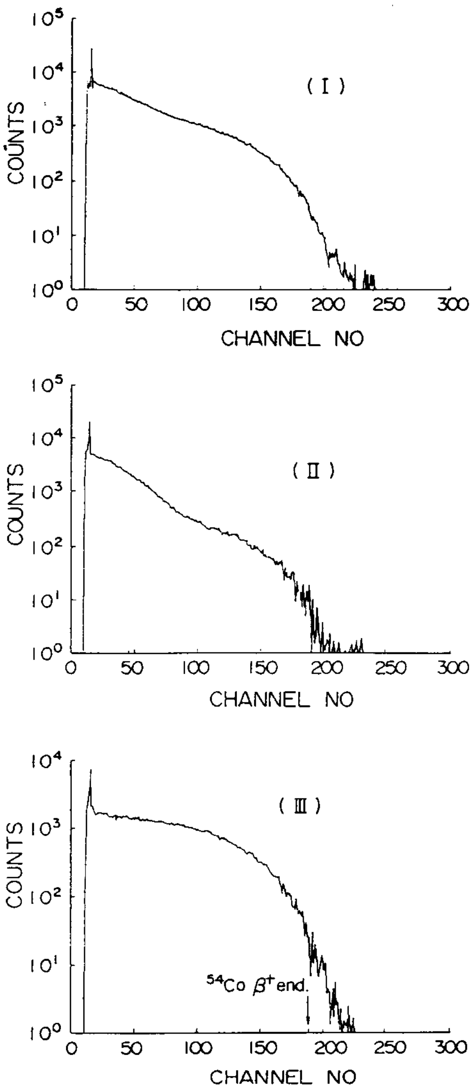

Fig. 3. Analysis of the positron spectrum; (I) is the raw spectrum and (II) and (III) are the "time filtered" spectra obtained by decomposing (I) by time-filtering of each channel. (II) is the long-lived part corresponding to ^{58}Cu, ^{54m}Co and others and (III) is the short-lived part corresponding to ^{54}Co and ^{57}Cu.