# Precision Half-Life Measurement of Tz = -1/2 Nuclei in the 1f7/2-Shell Region Using IGISOL

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| 著者 | Hama H., Shinozuka T., Yoshii M., Taguchi K., Kobayashi H., Suzuki S., Matsuura J., Kamiya T., Fujioka M. |
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# I. 7 Precision Half-Life Measurements of $T_z = -1/2$ Nuclei in the $1f_{7/2}$-Shell Region Using IGISOL

Hama H., Shinozuka T.*, Yoshii M., Taguchi K., Kobayashi H., Suzuki S., Matsuura J., Kamiya T. and Fujioka M.*
Department of Physics, Faculty of Science, Tohoku University
Cyclotron and Radioisotope Center, Tohoku University*

The properties of β-decay of $T_z = -1/2$ nuclei (mirror nuclei) in the sd-shell region were already studied precisely. But the experimental data are insufficient for the mirror nuclei in the $1f_{7/2}$-shell region. The success of mass separation of $^{57}$Cu ($T_{1/2}$ = 199 ms) by means of IGISOL[1] indicated a possibility of measuring short-lived nuclei having a small production cross section.

Half-life is one of the important information of β-decay with respect to the nuclear structure and the weak interaction. Among the eight mirror nuclei in the $f_{7/2}$-region we have observed $^{45}$V, $^{49}$Mn, $^{53g}$Co and $^{55}$Ni using IGISOL, and obtained their half-lives with small experimental errors.

The half-lives of these nuclei except for that of $^{53g}$Co were deduced from the time distributions of β-rays measured by a telescope consisting of plastic (NE102A) ΔE and E scintillation counters. This telescope configuration was indispensable for reducing the back-ground induced by neutrons and/or cosmic rays. To avoid the accumulation of long-lived radioisotopes a tape transport system was used.[2] The signals of coincidence between the ΔE and the E pulses were stored as the time signal of the β-rays using a home-made multi channel scaler.[3] A least-squares method was used to analyze the decay curves of β-rays. To calibrate the time axis we measured the decay of $^{54}$Co produced by the $^{54}$Fe(p,n) reaction using the same counting system and obtained its half-life to be 193.4±0.6 ms (Fig. 1), which agreed well with the previous value of 193.2±0.3 ms.[4,5]

$^{45}$V and $^{49}$Mn were produced by the $^{nat}$Ti(p,2n) and the $^{50}$Cr(p,2n) reactions, respectively. The proton beam from the AVF cyclotron had an energy of 30 MeV. In the case of $^{55}$Ni via the $^{54}$Fe($^3$He,2n) reaction, the $^3$He-beam energy was 27 MeV. The deduced half-lives of $^{45}$V, $^{49}$Mn and $^{55}$Ni are 534.9±9.8 ms, 381.8±7.8 ms and 200.6±3.3 ms, respectively. The results together with the previous ones are shown in Table 1. The present experimental errors are about 2 times smaller than the previous ones except for the case of $^{53}$Co.

Measurement of the half-life of $^{53}$Co is very difficult because it seems that the half-life of the ground state of $^{53}$Co is quite close to that of an isomeric state of $^{53}$Co; the half-life of this isomer was measured using the proton emission from the decay of the isomeric state by Cerny et al.[6] The previous value of the half-life of the ground state was obtained from the time spectrum of β-rays by Kochan et al.[7] to be 261±25 ms. It was uncertain, however, whether the β-rays from the decay of the isomer interfered their measurement. We could detect a de-excitation γ-ray from the 1329 KeV first-excited state of $^{53}$Fe following the β-decay of the ground state of $^{53}$Co. Although the 1329 KeV γ-ray is also populated from the decay of an isomeric state of $^{53}$Fe, the half-life of this isomer is so long (2.5 min) that its time distribution did not interfere with the present measurement. The time distribution of the 1329 KeV γ-ray measured in the present measurement is shown in Figure 2. The inset shows the proposed decay scheme of $^{53}$Co. We obtained $T_{1/2}$ = 267±109 ms as a preliminary value of the half-life of the ground state of $^{53}$Co, in agreement with the value obtained by Kochan et al.[7]

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Table 1. Results of half-life measurement of mirror nuclei using IGISOL at CYRIC, Tohoku University

| Nucleus | Reaction | Beam Energy(MeV) | Yield (atom/ C) | Half-Life(ms) | Previous Value(ms) | Ref. |
|---|---|---|---|---|---|---|
| $^{45}$V | $^{nat}$Ti(p,2n) | 30 | 4 | 534.9±9.8 | 539±18 | (1) |
| $^{49}$Mn | $^{50}$Cr(p,2n) | 30 | 14 | 381.8±7.8 | 384±17 | (2) |
| $^{53g}$Co | $^{54}$Fe(p,2n) | 30 | 15 | 267 ±109 | 262±25 | (3) |
| $^{55}$Ni | $^{54}$Fe($^{3}$He,2n) | 27 | 20 | 200.6±3.3 | 189± 5<br>208± 5 | (4)<br>(5) |
| $^{57}$Cu | $^{58}$Ni(p,2n) | 30 | 18 | 199.3±3.2 | 233±16 | (6) |

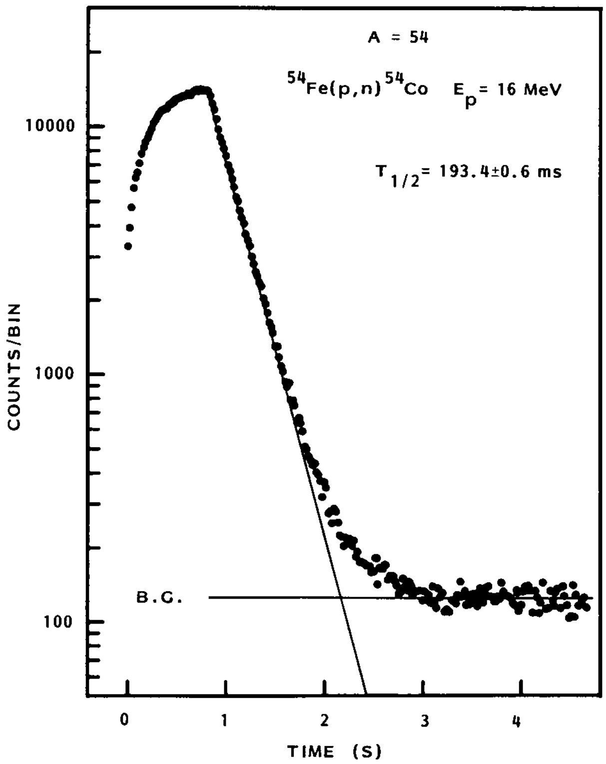


Fig. 1. Growth-decay curve of positrons from the decay of $^{54}Co$ produced via $^{54}Fe(p,n)$ reaction at $E_p$ = 16 MeV. Lines are components of the best fit to the function A + B·exp $(-\ln 2 \cdot t/T_{1/2})$.

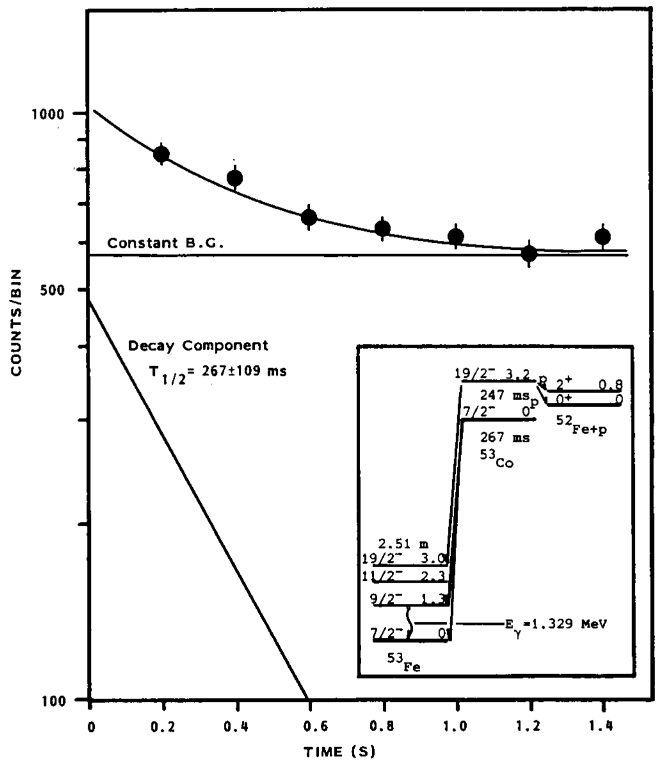


Fig. 2. Time distribution of the 1329 KeV γ-ray. The decay component is associated with the decay of the ground state of $^{53}Co$.