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著者	Arai Y., Tanaka E., Fujioka M., Shinozuka T., Matsumoto A., Miyatake H., Iura K., Ishimatsu T.
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Arai Y., Tanaka E., Fujioka M.*, Shinozuka T.*, Matsumoto A., Miyatake H., Iura K. and Ishimatsu T.
Department of Physics, Faculty of Science, Tohoku University
Cyclotron and Radioisotope Center, Tohoku University*

Using an isotope Separator on-line (ISOL) facility,[1] we studied the nuclear decay of a short-lived isotope ^{59}Zn, of which the half-life has been estimated[2] to be about 200 ms.

An ion source of hollow cathode type developed in this laboratory was used for the present experiment. A beam of 50 MeV ^{3}He-particles entered through a 0.5-mm thick BN window into the ion source, and then through another 0.3 mm thick BN window into a BN crucible, in which a natural Ni target in liquid phase at about 1500° C was held. Total energy loss of the ^{3}He beam in the two windows was estimated to be about 20 MeV. The crucible was open to the discharge region of the ion source, which was filled with Ar support gas about 10^{-4} Torr in pressure. At a beam intensity of 3 to 7 μA, the target was heated by the beam itself and no other heat sources were needed to keep the target at the appropriate temperature.

Mass analysis of the isotopes produced by the ^{3}He-particle bombardment of the Ni target was made with the isotope separator, and the isotopes with a mass number A of 59 were collected at the "collector station" on an aluminum layer deposited on a polyester tape. Motion of the tape was controlled by a tape transport system.[3]

Gamma rays emitted from the A=59 isotopes were measured at the collector station with a 96 cm^3 Ge(HP) detector. They were also measured at a "detector station" 60 cm apart from the collector station with a 76 cm^3 Ge(HP) detector. When the tape speed was so controlled that the collected isotopes took 14 s to move from the collector station to the detector station, 491 and 914 keV γ-rays were observed only at the collector station although the γ-rays following the β^+ decay of ^{59}Cu ($T_{1/2}$=82 s) were observed at both of the stations. This indicates that the 491 and 914 keV γ-rays result from the de-excitation of the levels in ^{59}Cu populated by the β^+ decay of ^{59}Zn with an estimated half-life of 200 ms.

It is expected that the ground state of ^{59}Zn decays predominantly by a superallowed β^+ transition to the ground state of its mirror nucleus ^{59}Cu. Taking advantage of this, we tried to determine Q for this transition from the Kurie plot of the β-ray spectrum. Positrons from the mass-separated A=59 isotopes were measured with a 5-cm^3 LEPS detector placed at the collector station. Fig. 1 shows the Kurie plot of the measured spectrum and the estimated end point. After correcting for energy losses of electron in a 16 μm Al-deposited polyester tape, a 20 μm Al window of the collector station and a 127 μm Be window of the LEPS, we have obtained from the end point energy of the β-ray spectrum the Q value for the decay of the ground state of ^{59}Zn,

$$Q = E^{\beta^+}_{max} + 2mc^2 = 9100 \pm 100 \text{ keV}.$$

The time spectrum of the total intensity of β- and γ-rays with energies above 300 keV emitted from the A=59 isotopes collected on the tape was measured with the LEPS at the collector station in a multi-channel scaling mode by repeating three successive steps: 1) collection of the mass-separated isotopes on a fresh spot of the tape for 0.8 s; 2) pause of collection for 2.0 s; 3) transfer of the tape to bring the fresh surface of the tape into the collector station. The experimental data and the result of a 2-component χ^2-fitting analysis of them are shown in Fig. 2; the half-life of ^{59}Zn has been determined to be

$$T_{1/2} = 183.7 \pm 2.3 \quad \text{ms}.$$

Assuming a branching ratio of 95 % for the transition to the ground state of ^{59}Cu, we have obtained the ft-value for the decay of the ground state of ^{59}Zn to be

$$ft = 4960 \pm 300, \quad \text{or} \quad \log(ft) = 3.70 \pm 0.03.$$

The Jyväskylä group[4)] has reported rĕcently that they observed delayed protons emitted from a ^{58}Ni target bombarded with 25 MeV ^{3}He-particles, and ascribed them to the proton decay of the excited states in ^{59}Cu populated by the β^+ decay of ^{59}Zn. To confirm the delayed proton emission following the β^+ decay of decay of ^{59}Zn, we measured protons emitted from the mass-separated A=59 isotopes. A 50 mm^2 × 500 μm Si(Au) detector was placed 2 cm apart from the isotope collection point along the direction of tape motion, and the distance between the tape surface and the front face of the detector was 8 mm. Repeating two successive steps; 1) tape transfer by 2 cm in 0.05 s, and 2) collection of the isotopes on a frech spot of the tape and simultaneous proton measurements with the Si(Au) detector for 0.6 s, we have obtained a proton spectrum quite similar to the one reported in Ref. 4. This result strongly supports the conclusion of the Jyväskylä group on the delayed proton emission.

References

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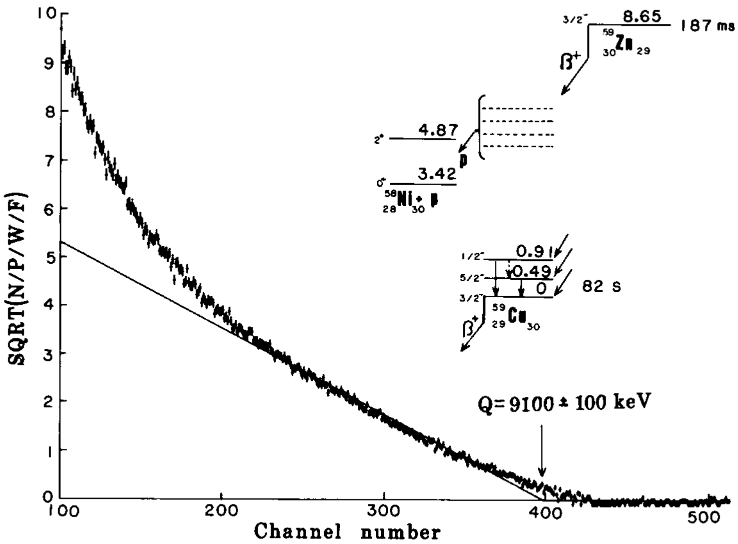

Fig. 1. Fermi-Kurie plot of the measured spectrum of β^+-rays emitted from the mass-separated A=59 isotopes. Non-linear χ^2-fitting to the data points between 200 th ch., which corresponds approximately to the Q value of ^{59}Cu, and 400 th ch. was done. A proposed decay scheme of ^{59}Zn is also shown. All energies are given in MeV relative to the ground state of ^{59}Cu.

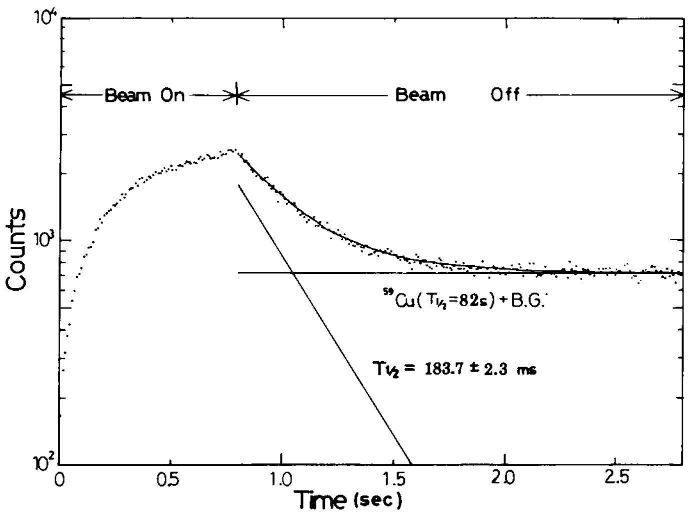

Fig. 2. Time spectrum of the total intensity of β^+- and γ-rays with energies above 300 keV emitted from the mass-separated A=59 isotopes. Dwell time per ch. is 10 ms. The spectrum was taken in a multi-channel scaling mode with a LEPS at the collector station by repeating successive three steps; 1) isotope collection on a fresh tape for 0.8 s, 2) pause of collection for 2.0 s, and 3) tape transfer to bring a fresh tape surface into the collector station.