Direct Precision Measurement of the Half-Llfe of 163Ho by Isotope-Dilution Mass Spectrometry for Neutrino-Mass Determination from Electron Capture

I. 16 Direct Precision Measurement of the Half-Life of ^{163}Ho by Isotope-Dilution Mass Spectrometry for Neutrino-Mass Determination from Electron Capture

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A direct determination of the quantity of a stable daughter nuclide formed by a parent nuclide is one of the reliable way to investigate the half-life of the parent nuclide. The isotope dilution mass spectrometry (IDMS) using a thermal ionization mass spectrometer is suitable for a precise determination of the number of nuclide. Therefore, in this study we used the IDMS methods for the determination of the half-life of ^{163}Ho.

Holmium-163 nuclide was produced with the ^{164}Dy(p,2n) reaction using the AVF cyclotron of the Cyclotron and Radioisotope Center, Tohoku University.[6] The ^{163}Ho was separated from the target Dy with an ion exchange method. A known amount of enriched ^{160}Dy, which was used for a spike, was added to the parent ^{163}Ho. After a period of 1.32 yr, the daughter Dy fraction was separated from the parent Ho fraction by the ion-exchange methods and the isotope ratios of DyO (m/e = 176∿180) were measured.

The isotope abundances of the target ^{164}Dy, the spike ^{160}Dy, the natural Dy and the parent ^{163}Ho were measured individually by the mass spectrometer. The number of the parent ^{163}Ho and the spike ^{160}Dy atoms were also measured by IDMS.

The separated daughter Dy fraction consisted of four components, i.e., the spike ^{160}Dy, the radiogenic ^{163}Dy, the target ^{164}Dy and the natural Dy. The number of atoms of each component was determined. The total half-life of ^{163}Ho ($T_{1/2}$) was calculated from the equation.

$$T_{1/2} = \frac{-t \times \ln 2}{\ln\{1-n(^{163}\mathrm{Dy})/n(^{163}\mathrm{Ho})\}},$$

where t is the standing period of the parent ^{163}Ho, $n(^{163}\mathrm{Dy})$ the number of radiogenic ^{163}Dy atoms and $n(^{163}\mathrm{Ho})$ the number of parent ^{163}Ho atoms. The

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calculation led to the value of $T_{1/2}$ = 4569±60 (95 % C.L.) for the half-life of ^{163}Ho.

Baisden et al.[5] also investigated the half-life of ^{163}Ho by measuring the production rate of ^{163}Dy due to the electron capture in ^{163}Ho by IDMS and obtained the result of 4570±50 yr. The agreement of the two values is excellent. The importance of this agreement cannot be overestimated because the experimental conditions of the two measurements are rather different.

Baisden et al. used about 0.7 mg of the parent ^{163}Ho and measured the isotope ratio of Dy over a period of 0.6 yr. On the other hand, in the present study only 0.0016 mg of ^{163}Ho was used for standing over a period of 1.3 yr. Moreover, Baisden et al. used the ^{159}Dy tracer for the column calibration, which was used for the separation of Ho and Dy, and measured the metal ion beams of Dy in their mass spectrometry. The existence of ^{159}Dy and NdO, whose mass numbers are equal to those of metal Dy ions, complicated the interpretation of the mass spectra. In our measurement the tracer Dy was not used and the monoxide ion beams of Dy were observed. Therefore, the interpretation of the mass spectra was simple.

The present result was used as a value to be published in the recent determination[7] of the electron neutrino mass, $m_{\nu e}$ < 550 eV (68 % C.L.).

References

1) Nauman R. A. et al., J. Inorg. Nucl. Chem. 15 (1960) 194.
2) Hopke P. K. et al., Phys. Rev. 171 (1968) 171.
3) Andersen J. U. et al., Phys. Lett. 113B (1983) 72.
4) Yasumi S. et al., Phys. Lett. 122B (1983) 461.
5) Baisden P. A. et al., Phys. Rev. C 28 (1983) 37.
6) Ishii K. et al., Nucl. Instr. Methods Phys. Res. 205 (1983) 563.
7) Yasumi S. et al., Phys. Lett. 181B (1986) 169.

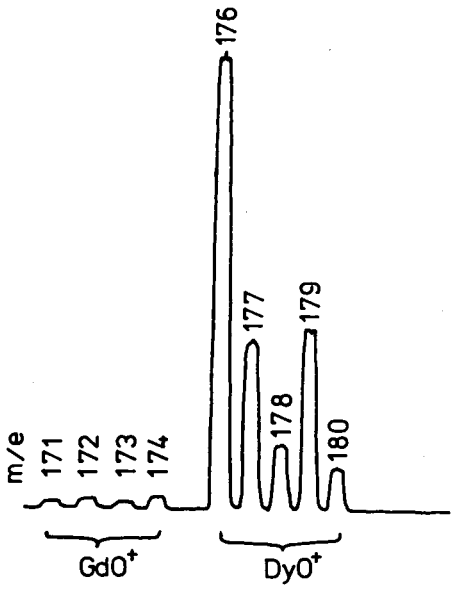

Fig. 1. Mass spectrum of the daughter Dy fraction.

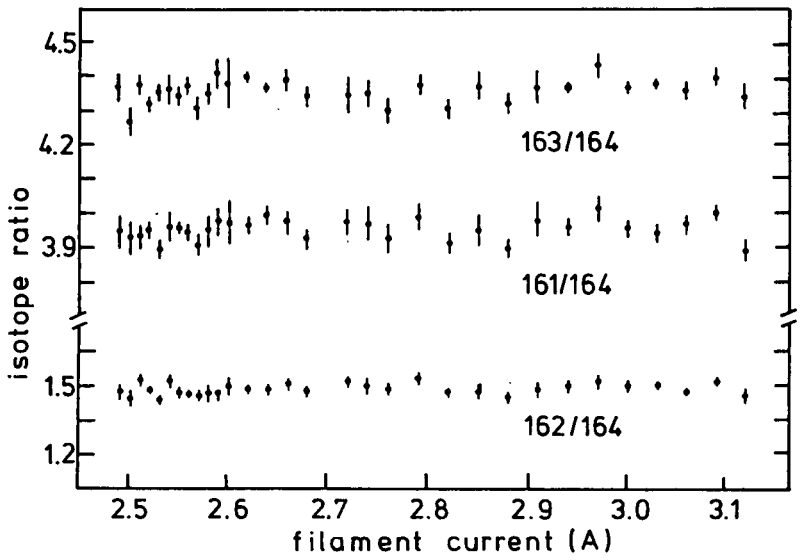

Fig. 2. Observed isotope ratios of Dy versus the filament current.