Excitation function measurement of the Tl$(d,\alpha)^{203}$Hg reaction for carrier-free ^{203}Hg tracer production

Y. Takahashi,[*1] S. Goto,[*1] D. Mori,[*2] T. Yokokita,[*2] Y. Komori,[*2] Y. Wang,[*2] and H. Haba[*2]

The influence of relativistic effects on orbital electrons is notable in the superheavy elements with the atomic number $Z \geq 104$. It is predicted that the influence is maximum in the group-12 element $_{112}$Cn according to a theoretical calculation.[1)] In order to confirm this prediction, we are planning chemical experiments on Hg as basic research for a chemical investigation of Cn. ^{203}Hg ($T_{1/2}$ = 46.594 d) is a suitable radionuclide to conduct off-line experiments because it has a relatively long half-life and emits measurable γ-rays. A carrier-free ^{203}Hg tracer can be produced with the $^{\rm nat}$Tl + d reaction, but only the excitation functions of Pb and Tl isotopes obtained with that reaction were measured in previous studies.[2–4)] In this study, we measured the excitation function of the ^{205}Tl$(d,\alpha)^{203}$Hg reaction.

The production cross sections of ^{203}Hg were measured by means of a stacked foil technique. $^{\rm nat}Tl_2O_3$ pellets (96.5 mg cm^{-2} thick) were covered with 0.01-mm-thick Al foil. These pellets and $^{\rm nat}$Ti foils (0.02 mm thick) were alternately stacked as a target. The $^{\rm nat}$Ti foils were used for monitoring the beam current and as an energy degrader. The target, fixed in a target holder, was irradiated with a 24-MeV deuteron beam supplied from the RIKEN AVF cyclotron for 2.5 h in He gas. The beam current was measured with a Faraday cup connected to the target holder, and the average current was about 90 nA. The deuteron energies in the individual pellets and foils were calculated with LISE++ ver. 11.2.[5)] After irradiation, the produced nuclides were identified and quantified by γ-ray spectrometry using Ge detectors.

Table 1 lists the identified nuclides and their nuclear data.

When each of ^{203}Pb and ^{203}Hg disintegrates, γ-rays of 279 keV are emitted. The radioactivity of each nuclides can be determined by analyzing the change of the count rate of the 279 keV peak against elapsed time because their half-lives are quite different. The obtained count rates of the 279 keV peak are shown in Fig. 1.

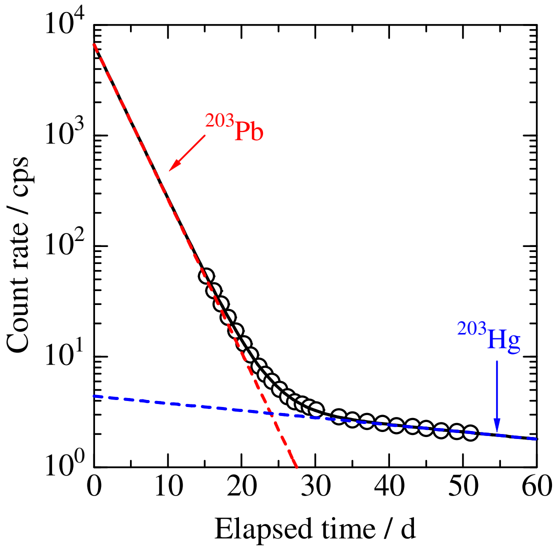

Fig. 1. Count rates of the 279 keV peak for one of the pellets. The solid curve indicates a fit of the experimental values based on Eq. (1). The dashed lines indicate the components of ^{203}Pb and ^{203}Hg.

The data in Fig. 1 can be fitted with the following equation:

$$C_{\rm tot} = C_{0,{\rm Pb}} \exp(-\lambda_{\rm Pb}\, t) + C_{0,{\rm Hg}} \exp(-\lambda_{\rm Hg}\, t). \quad (1)$$

where $C_{0,{\rm X}}$ and $\lambda_{\rm X}$ are the initial count rates and decay constant of a nuclide X of interest, respectively, and t is the elapsed time from the end of bombardment. The result of this analysis indicated that ^{203}Hg was certainly produced. The analysis is performed for all Tl pellets, and the determination of production cross sections of ^{203}Hg is in progress.

Table 1. Measured nuclides and their nuclear data.[6–9)]

Nuclide	Half-life		E_γ/keV	I_γ/%
^{204m}Pb	66.93	min	899.15	99.144
^{203}Pb	51.92	h	279.1952	80.9
^{202m}Pb	3.54	h	422.12	84.108
^{201g}Pb	9.33	h	311.15	76.90
^{202}Tl	12.31	d	439.51	91.5
^{201}Tl	3.0421	d	167.43	10.00
^{203}Hg	46.594	d	279.1952	81.56

*1 Graduate school of science and technology, Niigata University
*2 RIKEN Nishina Center

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