Determination of the ^{235}Th β-decay end point energy

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Sources of ^{235}Th were prepared by 14-MeV neutron irradiation of uranium followed by radiochemical separation. The β and γ spectra were measured with a semiconductor telescope and a HpGe detector, respectively. A β-decay end point energy of 1.44±0.05 MeV and a Q_β value of 1.47+0.08 MeV for ^{235}Th were determined.

To date, the ^{235}Th β-decay end point energy has not been measured directly. Because more than 90% of its β transitions feed the ground-state region of the daughter nucleus,[1] the method of single spectrum measurement is favorable.

The ^{235}Th was produced via the ^{238}U(n,α) reaction. Analytical-grade $UO_2(NO_3)_26H_2O$ was subject to ether extraction immediately prior to irradiation so as to remove ^{234}Th, the daughter of ^{238}U, and finally precipitated as $(NH_4)_2U_2O_7$. About 7g of $(NH_4)_2U_2O_7$ were irradiated for 20 min with 14-MeV neutrons from the Cockcroft-Walton of the Institute of Modern Physics (IMP). The irradiated target was dissolved in dilute nitric acid and the thorium activity was separated from uranium and most of the fission products by a solvent extraction cycle with 0.05M PMBP-$CHCL_3$. In order to remove the remaining fission products, an additional purification procedure based on coprecipitation was conducted. The thorium activity finally was extracted again into 0.05M PMBP-$CHCL_3$. The organic phase containing ^{235}Th was heated to dryness for the β- and γ-ray measurements which started 27 min after the end of the bombardment.

The β and γ spectra were measured with a semiconductor telescope β spectrometer and a HpGe detector, respectively. Both were shielded in a lead room. The measurements were made with the sample close to the detectors because of the limited source strength. Time sequence spectra were recorded on magnetic tape with an M-20 multichannel analyzer. After chemical treatments, the measured β spectra consisted only of ^{235}Th [$T_{1/2}\approx 7$ min (Refs. 1 and 3)] along with its daughter nucleus ^{235}Pa [$T_{1/2}\approx 24$ min (Refs. 1 and 3)] and a small amount of ^{234}Th [$T_{1/2}\approx 24$ d (Ref. 3) and its ^{234}Pa^m daughter [$T_{1/2}\approx 1.2$ min (Ref. 3)]. The measurements lasted 5 h, even though the half-life of ^{235}Th is only about 7 min, in order to resolve different components of the β spectra.

The measured time sequence spectra were resolved by using the radioactive-series decay analyzing program DECO.[2] The β-decay curves for ^{235}Th and ^{235}Pa were obtained (Fig. 1), and the half-lives for ^{235}Th and ^{235}Pa decay were determined to be 6.9±0.3 min and 24.7±0.6 min, respectively, in good agreement with the previous values.

After 4 h only ^{234}Th and its ^{234}Pa^m daughter were observable in the spectra. Measurements indicated that contributions from ^{234}Th and ^{234}Pa^m are negligible in comparison with ^{235}Th or ^{235}Pa in the early time intervals. Therefore, the ^{235}Pa β spectrum was obtained directly from the time sequence spectra between 50 and 78 min. The spectra between 0 and 8 min were taken as the total β spectrum, with an enhanced proportion of ^{235}Th due to its shorter lifetime. The β spectrum of ^{235}Th was obtained by subtracting the ^{235}Pa component from the total spectrum. The β spectra of ^{235}Th and ^{235}Pa determined in this manner are shown in Fig. 2. The end point energies were determined to be 1.4±0.05 MeV and 1.42±0.05 MeV for ^{235}Th and ^{235}Pa, respectively, by means of the iterative least-squares fitting program PAMUBE (Ref. 4) (for analyzing complex β spectra). The Fermi-Kurie plots are shown in Fig. 3. The end point en-

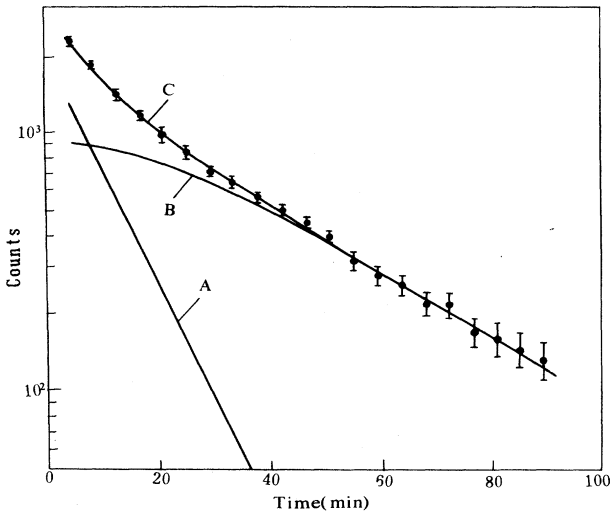

FIG. 1 Decay curves for ^{235}Th, ^{235}Pa and the sum of them in comparison with experimental data. *A*, calculated curve for ^{235}Th; *B*, calculated curve for ^{235}Pa; *C*, calculated curve for the sum of them. (Filled circles indicate experimental values.)

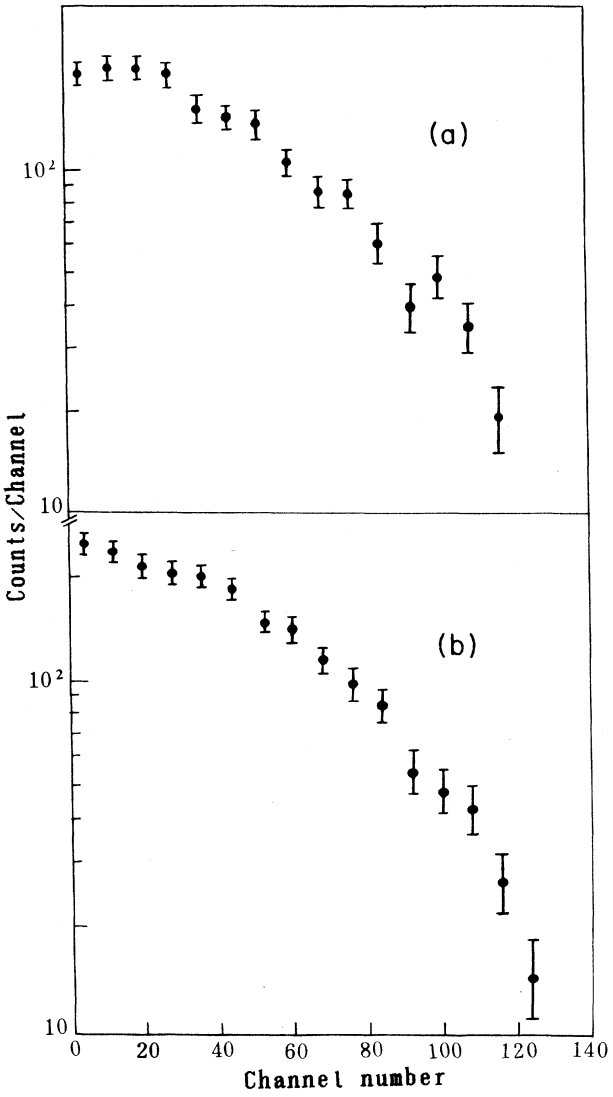

FIG. 2. β spectra for ^{235}Pa (a) and ^{235}Th (b).

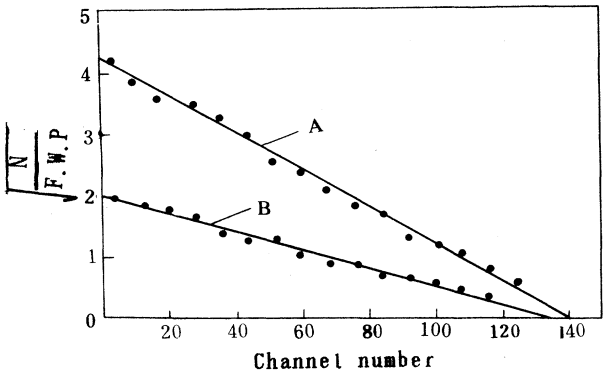

FIG. 3. Fermi-Kurie plots of β spectra for ^{235}Th (a) and ^{235}Pa (b).

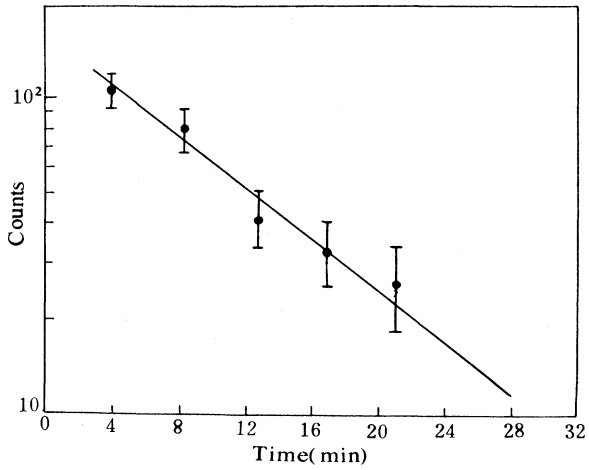

FIG. 4. Decay curve for 417.0- keV γ ray.

ergy obtained for ^{235}Pa is in good agreement with the previous value.

By carefully following the decay of the most intense γ ray (417.0 keV), the ^{235}Th half-life was determined to be 7.3±0.3 min (Fig. 4), which agrees with the 6.9±0.3 min determined from our β measurement. By using the calibrated efficiencies of the γ and β detectors and the measured β-ray intensity, the absolute intensity of the 417.0 keV γ ray was roughly estimated to be 2±1 per 100 disintegrations. This supports the partial decay scheme of ^{235}Th given by Mirzadeh *et al.*[11] Finally, on the basis of the partial decay scheme, the ^{235}Th Q_β was determined to be 1.47±0.08 MeV.

Table I summarizes the previously determined disintegration energy values for the β decay of ^{235}Th. There is good agreement between the present Q_β value and that of Ref. 8, but larger discrepancies between our Q_β value and those of Refs. 5–7, 9, 10, and 12. The reason for this discrepancy is not clear. The availability of a more complete decay scheme might lead to a possible explanation.

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TABLE I. Q_β values for the β decay of ^{235}Th.

Reference	Q_β (MeV)
Zeldes *et al.* (Ref. 5)	2.14
Garvey *et al.* (Ref. 6)	2.04
Kolesnikov and Demin (Ref. 7)	1.83
Asghar *et al.* (Ref. 8)	1.44±0.08
Wapstra and Bos (Ref. 9)	1.84
Wagemans *et al.* (Ref. 10)	1.92±0.16
Wapstra and Audi (Ref. 12)	1.94±0.11
This work	1.47±0.08

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