PHYSICAL REVIEW C VOLUME 10, NUMBER 1 JULY 1974

Redetermination of the half-life of ^{235}U for α emission

A. J. Deruytter*
Centraal Bureau voor Nucleaire Metingen, 2440 Geel, Belgium

Gerda Wegener-Penning†
Studiecentrum voor Kernenergie, 2400 Mol, Belgium
(Received 30 January 1974)

Measurements with a low counting geometry and a 99.999% ^{235}U source were carried out to determine branching ratios in the α decay. The ^{235}U half-life was calculated, relative to that of ^{238}U. The result is $T_{1/2}(^{235}U) = (6.85 \pm 0.09) \times 10^8$ yr.

[RADIOACTIVITY ^{235}U; measured α-decay branching; deduced $T_{1/2}$ α emission.]

Recently Jaffey and co-workers[1] remeasured the half-life for α emission. They obtained a value which is about 1% lower than the results of earlier specific activity measurements (see Table I), and in better agreement with the results from other measurements based on the comparison of activity ^{238}U or ^{234}U in the α spectrum of natural uranium. The most recent relative measurement was done by Deruytter.[2] The result he obtained relies on the branching ratio $X = 0.86$, as determined by Ghiorso,[3] which is used in the formula

$$T_{1/2}(^{235}U) = T_{1/2}(^{238}U)\frac{N_{235}}{N_{238}}\frac{X}{R} \qquad (1)$$

with

$$X = \frac{n_c}{n_{235}}, \quad R = \frac{n_c}{n_{238}},$$

where N is the amount of isotope present, n the number of registered counts, $T_{1/2}$ the half-life, and the subscript c denotes the central peak in ^{235}U. White, Wall, and Pontet[4] obtained for X the value 0.874 ± 0.080. Using that X value in formula (1) a half-life value is obtained which is in agreement with Jaffey's result. The purest sample used by White contained an amount of 0.6% uranium isotopes other than ^{235}U.

We remeasured the branching ratio with a sample having 99.999% ^{235}U.[9] Extreme care was taken to avoid ^{234}U impurities and contamination by other α emitters and it consisted of 10 $\mu g/cm^2$ uranylacetate on a Plexiglass backing. The use of such a thin source minimized backscattering and self-absorption of the α particles in the source. No heavy metal backing was used to reduce the backscattering by the source support. A low counting geometry was used.

The α spectrum was measured by means of a surface barrier detector. Sample and detector were mounted in a vacuum Al chamber. Further electronic apparatus consisted of a charge sensitive preamplifier, biased amplifier, and a 400-channel pulse height analyser. 12 α spectra, each of high statistical accuracy (3×10^4 counts), were recorded. The sum spectrum is shown in Fig. 1.

To calculate accurately the intensity of the central peak situated around 4.35 MeV, three contributions must be taken into account: (1) the tailing on the low energy side and the fraction under the 4.20 MeV line; (2) the number of counts in the central peak; and (3) the number of counts of the central peak in the overlap region with the 4.5 MeV peak.

The first contribution was calculated by fitting an exponential function through the experimental points of the tailing and by extrapolating that function under the 4.2 MeV line until it joined smoothly the low-energy side of the central peak. The third contribution was calculated in an analogous way: An exponential function was fitted to the high-energy side of the central peak and extrapolated under the third peak. This was done as well for each separate spectrum as for the sum spectrum.

The average from the single results is (cfr. Table II):

$$\langle X \rangle = 0.8452 \pm 0.0016,$$

where the indicated error is the 95% confidence limit calculated from a Student t test. The dispersion range of the results is

$$T = s\,t\ (12\text{ dof};\ p = 95\%) = 0.0062,$$

where s is the dispersion and t the Student factor for 12 degrees of freedom and a 95% probability. The branching ratio calculated from the sum spectrum, $X = 0.8463$, is consistent with the $\langle X \rangle$ value; the significance level even exceeds 80%. The half-life calculated from formula (1), and based on numerical values of T_{238}, N_{235}/N_{238}, and R as used

TABLE I. Experimental results for the ^{235}U half-life.

Author	Reference	Method	Material	$T_{1/2}(^{235}U)$
Sayag	6	Comparison of the α activity of ^{235}U and ^{234}U in natural uranium	Natural uranium	$(6.94 \pm 0.25) \times 10^8$ yr
Würger	8	id.	id.	$(6.84 \pm 0.15) \times 10^8$ yr
Deruytter	2	Comparison of the α activity of ^{235}U and ^{238}U in natural uranium	id.	$(6.92 \pm 0.09) \times 10^8$ yr
Fleming	7	Specific activity measurement	99.94% ^{235}U	$(7.12 \pm 0.16) \times 10^8$ yr
Knight	5	id.	id.	$(7.10 \pm 0.16) \times 10^8$ yr
White	4	id.	id.	$(7.12 \pm 0.09) \times 10^8$ yr
Jaffey	1	id.	99.999% ^{235}U	$(7.038 \pm 0.005) \times 10^8$ yr
This work		X determination	99.999% ^{235}U	$(6.85 \pm 0.09) \times 10^8$ yr

by Deruytter in Ref. 2 is

$$T_{1/2}(^{235}U) = (6.85 \pm 0.09) \times 10^8 \text{ yr} .$$

This value is not in agreement with Jaffey's result, but in good agreement with other results from relative measurements. If we use the $T_{1/2}(^{238}U)$ value as found by Jaffey in the same experiment the disagreement increases:

$$T_{1/2}(^{235}U) = (6.76 \pm 0.09) \times 10^8 \text{ yr} .$$

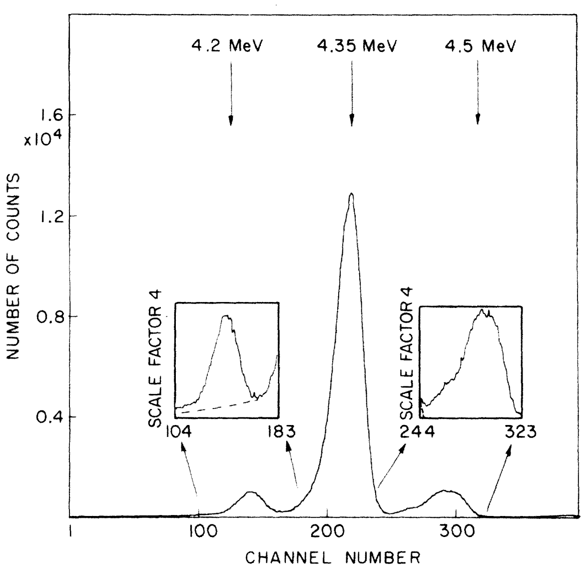

FIG. 1. Experimental energy spectrum of the ^{235}U α particles. Dotted lines in the inserts indicate contribution of the central line (4.35 MeV) to the side peaks.

However, close examination of the ^{235}U α spectrum shown in Jaffey's paper (Ref. 1, Fig. 5) seems to indicate it to be almost identical with the one we obtained. Jaffey's spectrum would probably yield a branching ratio comparable with our own X value and hence a $T_{1/2}(^{235}U)$ in disagreement with the result of Jaffey's own specific activity measurements.

The authors are indebted to Dr. M. Nève de Mévergnies for reading carefully the manuscript.

TABLE II. Values of the branching ratio (or the abundance of the 4.35 MeV line in the α spectrum of ^{235}U), as calculated from the experimental energy spectra.

	Branching ratio X_i	Statistical error S_i	Number of counts N_i
	0.8506	0.0091	38 444
	0.8448	0.0101	31 467
	0.8412	0.0088	39 464
	0.8461	0.0091	37 354
	0.8448	0.0099	31 547
	0.8470	0.0098	32 295
	0.8472	0.0095	34 321
	0.8431	0.0097	32 873
	0.8400	0.0095	34 168
	0.8476	0.0099	31 380
	0.8443	0.0090	38 185
	0.8453	0.0096	33 920
$\langle X \rangle$	0.8452	0.0026 [a]	
X sum spectrum	0.8463	0.0027	415 418

[a] Error on $\langle X \rangle$ calculated by

$$\frac{1}{12}\left[\sum_i (S_i)^2\right]^{1/2}.$$

*Present address: Rijksuniversiteit Gent, Proeftuinstraat, 9000 Gent, Belgium.

†I.W.O.N.L. post doctoral fellow.

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[9]The material was obtained from the U. S. Atomic Energy Commission Research Material Pool and the source was prepared by the Sample Preparation Group of Central Bureau for Nuclear Measurements, Geel.