Half-lives of the actinide nuclei ^{225}Th, ^{226}Th, ^{223}Ac, and ^{226}Ac

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Improved values for the half-lives of the nuclei ^{225,226}Th and ^{223,226}Ac have been obtained in the course of an experiment on the photodisintegration of ^{232}Th. The values of several other half-lives in the same mass region were also measured and found to be consistent with previous, but more accurate, determinations.

The values reported here for the half-lives of several actinide nuclei were measured in an experiment[1] whose principal aim was the investigation of the cross section for multiple nucleon emission from ^{232}Th following excitation by medium energy photons.

Thin ^{232}Th deposits, typically 40–80 μg/cm^2, on 0.12 mm aluminum backings were irradiated with bremsstrahlung beams at endpoint energies between 40 and 150 MeV. Repeated short irradiations of about 8 min were used to examine the relatively short-lived products. These were followed by a longer irradiation ($\sim$10 h), after which the samples were counted over a period of up to 12 months. The radioactive products were identified by counting their α emissions using a solid-state detector in reproducible geometry giving a solid angle of 1.75 sr. Long term stability checks and relative normalizations were possible using the natural α-decay lines from the ^{232}Th target material.

The overall energy resolution of 35 keV, to which the target thickness and intrinsic detector resolution both contribute significantly, is not sufficient to resolve all of the α lines in the complex spectra observed. The complexity varies considerably both with the bremsstrahlung endpoint energy and the length of time which has elapsed since the irradiation, but on the average it is possible in each spectrum to separate and follow the decay of seven single α lines, five doublets, and four more complicated multiplets.

In fitting the appropriate decay function to each α line or group it was, in general, possible to carry out a linear least squares fit using known decay constants. However,

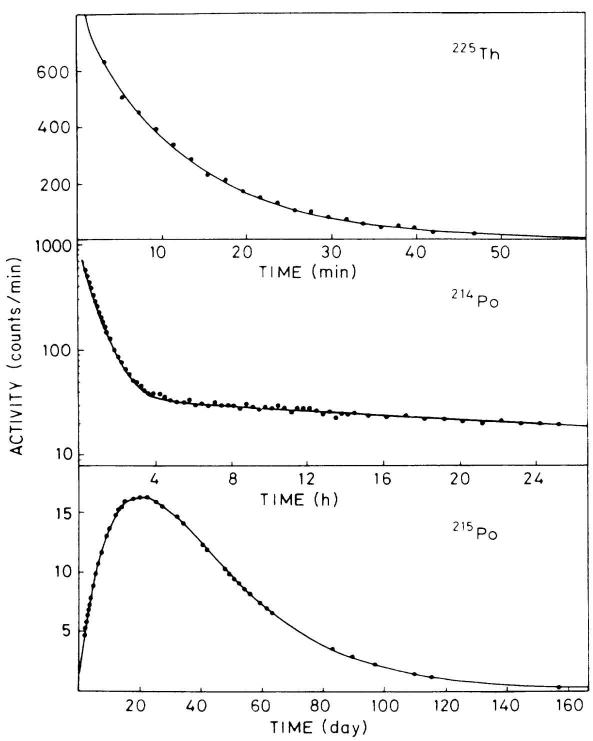

FIG. 1. The observed decay and least-squares fits of three α-emitting nuclei produced in this experiment: (a) the 6.798 MeV α line from ^{225}Th(8.7 min), (b) the 7.687 MeV α line from ^{214}Po characterized by the parent decay ^{226}Ac(29 h)$\rightarrow$^{226}Th(31 min), and (c) the 7.386 MeV α line from ^{215}Po with parent activity ^{227}Th(18.7 d)$\rightarrow$^{223}Ra(11.4 d).

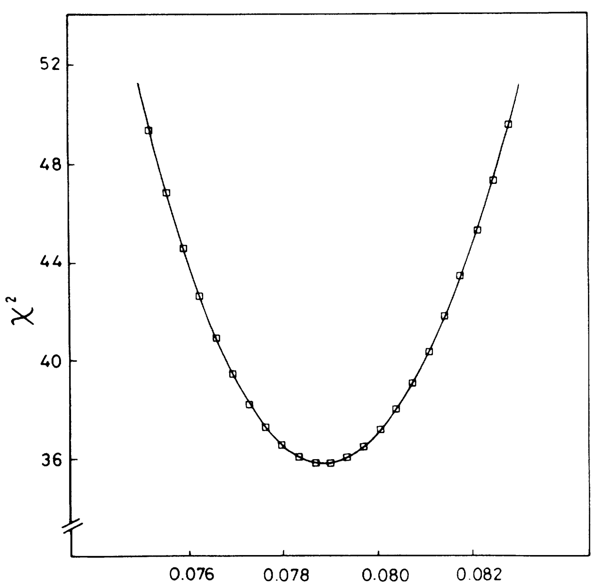

FIG. 2. Determination of the ^{225}Th decay constant λ using a search routine to fit this one nonlinear parameter. The χ^2 function is parabolic and has a minimum at 35.8 for 37 degrees of freedom.

TABLE I. A comparison of the half-lives obtained in the present experiment with previously determined values. Results in the upper part of the table represent improved values.

Nuclide	Present work	Number of measurements	Previous values	Ref.
^{225}Th	8.72±0.04 min	41	8.0±0.5 min	3
^{226}Th	30.57±0.10 min	39	30.9 min	4
^{223}Ac	2.10±0.05 min	21	2.2±0.1 min	3
^{226}Ac	29.37±0.12 h	14	29 h	5
^{227}Th	18.738±0.054 d	15	18.7176±0.0052 d	6
			18.6±0.1 d	7
			18.169±0.084 d	8
^{224}Ac	2.55±0.28 h	9	2.9±0.2 h	3
^{223}Ra	11.444±0.046 d	15	11.4346±0.0011 d	9
			11.22±0.05 d	10
			11.685±0.056 d	8
^{225}Ra	15.02±0.56 d	8	14.8±0.2 d	11

in those cases where one or more half-life was not well established, these parameters were also determined using a "parameter search" method to obtain the best fit. In this case the errors were obtained as described in Ref. 2. A determination of the half-lives was also carried out for cases in which the values are already well established, as a check on the reliability of the present results.

The counting rates were low so that dead-time corrections were always less than 0.2%. When the counting periods became comparable with the half-lives, the fitting functions were appropriately modified. These and other precautions appear to have been successful in eliminating systematic errors. The quality of the fits was good and entirely consistent with the statistical errors in the data. Figure 1 shows three such fits. Figure 2 shows the determination of the ^{225}Th half-life by the search procedure.

Several independent values were obtained for each half-life since repeated irradiations were carried out at each of the bremsstrahlung endpoint energies. In addition, some half-lives could be evaluated from the decay of more than one α line or group. The values obtained showed no correlation with endpoint energy or the decay curve from which they were evaluated. The spread in the values obtained was entirely consistent with the statistical accuracy of the individual values. Table I presents the final weighted means of the half-life values obtained.

The new values represent a clear improvement in accuracy[3–5] for the four nuclei ^{225,226}Th and ^{223,226}Ac. The remaining four values are consistent with the presently accepted numbers,[6–11] thus giving confidence in the experimental accuracy.

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