Decay of Sc^{47}

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(Received April 18, 1955)

Sc^{47} was milked from Ca^{47}, prepared by proton irradiation of CaO, and its radiations were studied by coincidence and gamma-ray spectrometry. Sc^{47} was found to decay with the emission of beta rays of 0.46 $\pm$0.02 and 0.62$\pm$0.03 Mev maximum energy. 66$\pm$3% of the decay is accompanied by a 0.157$\pm$0.007 Mev gamma ray in coincidence with the 0.46-Mev beta rays.

THE radioisotope Sc^{47} was studied to determine its decay scheme, since recent published values (see Table I) show considerable disagreement in the energy values of the beta and gamma components.[1–4] Knowledge of the decay scheme is of special interest because the radioisotope appears to have a relatively simple decay scheme, an almost unconverted gamma ray, beta-gamma coincidences permitting determination of its activity, and a half-life of several days. When the gamma/beta ratio is known, it may be used in the calibration of gamma detectors for the elucidation of decay schemes involving gamma rays of low energy.

PROCEDURE AND DISCUSSION

Calcium oxide was irradiated with 14-Mev protons in the ORNL 86-inch cyclotron. Following irradiation, the CaO was dissolved in nitric acid and the *p*H of the solution adjusted to between 1 and 2 by the addition of dilute sodium hydroxide. The product scandium, and the trivalent radioisotopes which resulted from the irradiation of strontium and barium impurities, were removed by repeated extractions with 0.5*M* thenoyltrifluoroacetone (TTA) in xylene.[5] Identified in the organic fraction were Sc^{43}, Sc^{44}, Sc^{46}, Sc^{47}, and Sc^{48}, which are known to be produced by proton bombardment of calcium.

The aqueous solution was made slightly acid and heated, saturated oxalic acid added, and the solution cooled. The precipitated calcium oxalate was filtered, washed, dissolved in dilute HCl, and the calcium oxalate reprecipitated. The calcium oxalate was then ignited to calcium oxide in a furnace. A portion of this precipitate was examined daily with a 3 in.$\times$3 in. NaI(Tl) gamma-ray spectrometer to follow the growth of the 157-kev photopeak from Sc^{47}.

After one week, the precipitate was dissolved, its *p*H adjusted to between 1 and 2, and the Sc^{47} extracted with 0.5*M* TTA in xylene. The organic fraction was washed three times with water at *p*H 1.5, and the Sc^{47} was extracted from the organic phase with 2*M* nitric acid. Aliquots of this solution were used in the subsequent measurements.

The decay of Sc^{47} was followed for 20 days with an end-window Geiger-Müller beta counter, with a well-type gamma scintillation counter, and with a gamma

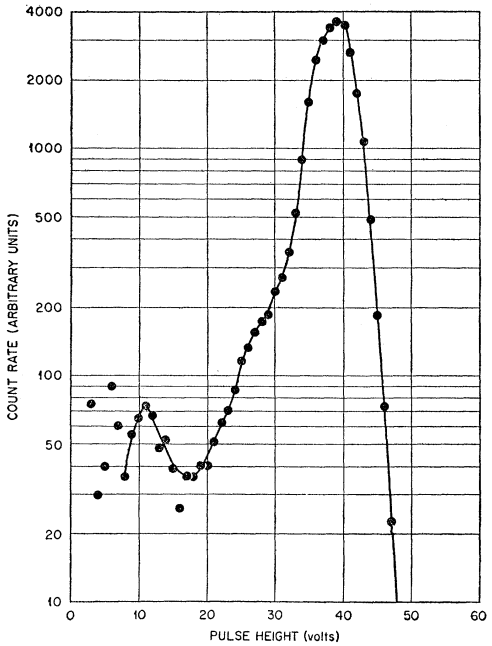

FIG. 1. Gamma-ray spectrum of Sc^{47}.

TABLE I. Previously reported decay data for Sc^{47}.

Beta energy (Mev)	γ energy (Mev)	Comments	Ref.
0.622 (34$\pm$4%)[a]	0.185$\pm$0.007[b,c]	(0.434β–0.185γ) Coinc.	1
0.434 (66$\pm$4%)[a]			
0.64$\pm$0.03 (100%)[d]	0.159.5[b,e,c]	(0.64 β–0.160γ) Coinc.	2
0.286 (28%)[d]	0.218[c]		3
0.490 (72%)			
0.52[f]	0.16[b]	γ/β=5/4	4

[a] Lens spectrometer.
[b] Scintillation spectrometer.
[c] Conv. e^--spectrometer.
[d] Double-focusing magnetic spectrometer.
[e] Photoelectron spectrometer.
[f] Al absorption data.

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[1] L. S. Cheng and M. L. Pool, Phys. Rev. **90**, 886 (1953).
[2] Cork, Leblanc, Brice, and Nester, Phys. Rev. **92**, 367 (1953).
[3] Luis Marquez, Phys. Rev. **92**, 1511 (1953).
[4] Aten, Greuell, and Van Dijk, Physica **19**, 1049 (1953).
[5] A. Broido, U. S. Atomic Energy Commission Report AECD-2616, 1947 (unpublished).

spectrometer adjusted to count only the photoelectric peak from the 0.157-Mev gamma ray. A 3.45±0.10 day half-life was obtained by these counting methods.

Beta-gamma coincidence measurements, using a proportional counter for beta detection and a 3 in. ×3 in. NaI(Tl) crystal spectrometer as the gamma detector, indicated that a gamma ray was in coincidence with a beta group. The slope of the absorption curve, using aluminum before the beta detector, yielded a maximum beta energy of 0.46±0.02 Mev for this group. From range measurements, a maximum energy of 0.62±0.03 Mev was obtained for the non-coincident beta group. The energy of the gamma ray was found to be 12 kev higher than that of Ce^{141},

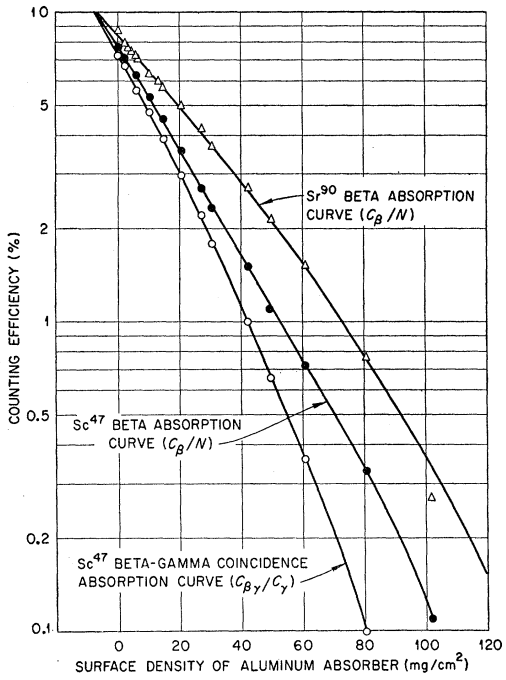

FIG. 2. Variation of β counting efficiency of Sc^{47} and Sr^{90} as a function of aluminum absorber.

indicating an energy of 0.157±0.007 Mev. No other gamma ray was found.

The number of gamma rays per disintegration was obtained in two ways. One method consisted of determining the number of gamma rays by absorption in the 3 in.×3 in. NaI(Tl) crystal, and determining the total disintegrations by 4π-coincidence counting. Using attentuation coefficients for 0.15-Mev gamma rays,[6] and integrating graphically, the total absorption was computed to be 92%, and the photoelectric absorption 88%. Since the total area under the curve in Fig. 1 includes counts contributed by degraded radiation scattered into the crystal from the surroundings, only the area under the photoelectric peak was measured.

[6] G. R. White, National Bureau of Standards Report 1003, 1952 (unpublished).

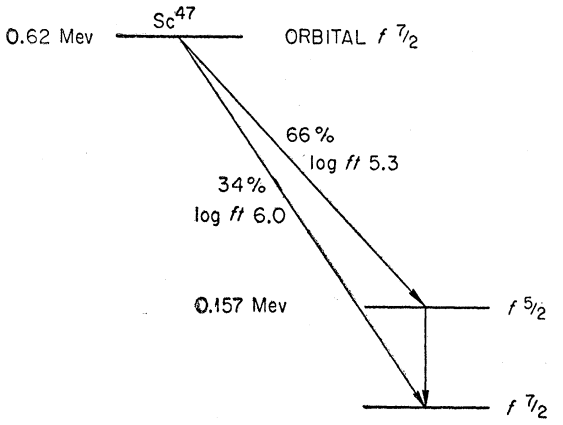

FIG. 3. Decay scheme of Sc^{47}.

The gamma disintegration rate, N_γ, was found by

$$N_\gamma = C_\gamma/[\epsilon\omega(1-m_I)(1-m_a)], \quad (1)$$

where C_γ is the gamma count rate calculated from the area under the photoelectric peak, ϵ is the fraction of gamma rays entering the crystal which are completely absorbed by photoelectric absorption (0.88) and by multiple processes (assumed to be 0.01), ω is the fraction of the angle subtended at the source by the crystal (0.262), m_I is the fraction of escaping iodine x-rays (0.014), and m_a is the fraction of gamma rays absorbed in the beryllium beta absorber, the aluminum container, and the magnesium oxide reflector (0.041). The ratio of gamma rays to total activity was thus found to be 0.66±0.03.

In the second method, the gamma/beta ratio, f, was calculated from $\beta-\gamma$ coincidence data, by using the equation

$$\frac{C_{\text{beta}}C_{\text{gamma}}}{C_{\beta-\gamma}N} = f\left(1-\frac{e_{\beta 2}}{e_{\beta 1}}\right)+\frac{e_{\beta 2}}{e_{\beta 1}}+c\left(\frac{e_c}{e_{\beta 1}}-e_c\right), \quad (2)$$

where the C's are count rates, N is the disintegration rate, c is the ratio of conversion electrons to total activity, and e is the counting efficiency for the two beta groups and the conversion electrons. The efficiency of the weak beta group, $e_{\beta 1}$, is the ratio of coincidence to gamma counts shown in Fig. 2. In evaluating $e_{\beta 2}$, the efficiency of the strong beta group, the counting efficiency of Sr^{90} (maximum beta energy 0.6 Mev), was used. The Sr^{90} was separated from its Y^{90} daughter and its activity determined by absolute beta counting. An approximate value of c can be found by extrapolating the values of C to zero absorber, in which case $e_{\beta 1}$ equals $e_{\beta 2}$, and the first term on the right-hand side in Eq. (2) is eliminated, while the second equals unity. In repeated determinations, the value of the left-hand side of the equation is 1.00, indicating that c is very small. A search for titanium x-rays was made with an argon-methane filled proportional counter spectrometer, but none were

found, giving further indication that the conversion coefficient is small. Hence, the last term in the equation was omitted and the equation solved for f at the experimental points shown in Fig. 2. A value of 0.68 $\pm$0.04 was obtained, with no significant trend being observed in the values of f as the amount of aluminum absorber was changed.

CONCLUSION

These data confirm the decay scheme proposed by Cheng and Pool.[1] However, the gamma-ray energy was found to be 157 kev instead of the reported 185 kev.

Nuclear shell theory predicts ground states of $f_{7/2}$ in both Sc^{47} and Ti^{47}. The logft value was calculated to be 6.0 for the 0.62-Mev β ray and 5.3 for the 0.46-Mev β ray. These logft values indicate[7] that both beta groups fall in the $\Delta I=0$, 1 (no) allowed classification. A level scheme consistent with these data is shown in Fig. 3. The assignment of $f_{5/2}$ to the excited state in Ti^{47} would thus make the 157-kev gamma a magnetic dipole transition. The only reported conversion coefficient,[1] 3.6×10^{-3}, falls within the range predicted for either electric or magnetic dipole.[8]

ACKNOWLEDGMENTS

The authors are indebted to Farno Green, who suggested the problem and supervised the irradiations.

[7] Mayer, Moszkowski, and Nordheim, Revs. Modern Phys. **23**, 315 (1951).
[8] M. E. Rose *et al.*, Phys. Rev. **83**, 79 (1951).

PHYSICAL REVIEW VOLUME 99, NUMBER 3 AUGUST 1, 1955

Fission of U^{235} by 14-Mev Neutrons: Nuclear Charge Distribution and Yield Fine Structure*

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(Received December 20, 1954)

The following results were derived from experiments in which iodine was quickly separated from irradiated uranium metal at a known time after irradiation. The fractional chain yields are based on the cumulative chain yields at iodine.

	Ratio of cumulative yields, 14-Mev/thermal neutron fission	Fractional chain yield 14-Mev	Thermal
I^{131}	1.48 $\pm$0.07	<0.08	<0.01
Te^{131m}	5.5 $\pm$1.5	0.35 $\pm$0.05	<0.05
Te^{131}	...	<0.30	<0.03
I^{132}	1.12 $\pm$0.02	0.16 $\pm$0.01	<0.01
Te^{132}	0.97 $\pm$0.02	...	...
I^{133}	0.81 $\pm$0.03	<0.40	<0.05
Te^{133m}	0.64 $\pm$0.15	...	...
Te^{133}	...	<0.40	<0.1
I^{134}	0.65 $\pm$0.02	0.43 $\pm$0.02	0.11 $\pm$0.02
I^{135}	0.69 $\pm$0.02	...	...

The error given is the standard deviation of the average of the experimental results; it does not include the 4 percent standard deviation for the ratio of 14-Mev to thermal neutron fission yields of Mo^{99} used in the calculation of the ratio of cumulative yields. The results indicate that the pronounced peak in the mass-yield curve found at mass number 134 in thermal-neutron fission is nearly washed out in 14-Mev-neutron fission. The higher independent yields of late members of the chains in 14-Mev-neutron fission indicate a shift toward stability of the most probable initial nuclear charge. This shift is about 0.7 charge unit for the chains in the mass region studied.

As by-products of the work, the following half-life values were determined: I^{133}, 20.9$\pm$0.3 hour; I^{132}, 2.30$\pm$0.05 hour; fission precursor of I^{135}, <0.4 minute.

INTRODUCTION

THIS paper presents the results of experiments carried out during the summer of 1951. Prior to the start of this work, Ford and Gilmore[1] had measured the relative cumulative 14-Mev and thermal-neutron yields of I^{131}, and Glendenin[2] had reported values for the independent yields of I^{134} and I^{133} formed in thermal-neutron fission. Pappas,[3,4] in determining the thermal-neutron fission yields of the antimony, tellurium, and iodine isotopes, also obtained a value for the independent yield I^{133}(+2-min Te^{133}).

The general procedure followed was to irradiate for a short time a stack of two or more pieces of uranium metal in a flux of 14-Mev or thermal neutrons. One piece was dissolved immediately after the irradiation, and the iodine quickly separated. The iodine activities in this sample, corrected for the small growth from

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
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[1] G. P. Ford and J. S. Gilmore (private communication from the Los Alamos Scientific Laboratory).
[2] L. E. Glendenin, Technical Report No. 35, Laboratory for Nuclear Science, Massachusetts Institute of Technology, 1949 (unpublished).
[3] A. C. Pappas, Technical Report No. 63, Laboratory for Nuclear Science, Massachusetts Institute of Technology, 1953 (unpublished).
[4] A. C. Pappas, Progress Report, Laboratory for Nuclear Science, Massachustetts Institute of Technology, May, 1951 (unpublished).