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Disintegration of Sc^{47}

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The disintegration of Sc^{47} has been investigated with the help of magnetic spectrometers, scintillation spectrometers, and coincidence counting. There are two beta-ray groups of end-point energies 0.600±0.002 (40%) and 0.439±0.002 (60%) Mev, and one gamma ray of 0.159 Mev. The gamma ray is in coincidence with the lower energy group.

PREVIOUS EXPERIMENTS

THE mode of decay of the isotope Sc^{47} has been the subject of a number of investigations which give widely discordant results. For this reason we decided to remeasure the spectrum.

Cheng and Pool[1] found beta-ray groups of 0.622 (34%) and 0.434 (66%) Mev using a magnetic lens spectrometer. One gamma ray, having an energy of 0.185 Mev was found using a scintillation spectrometer and internal conversion electrons were found for the gamma ray in the magnetic lens. Beta-gamma coincidence experiments, using a scintillation counter for the gamma ray and a Geiger counter with aluminum absorption for the beta rays, showed the lower energy beta-ray group was in coincidence with the gamma ray.

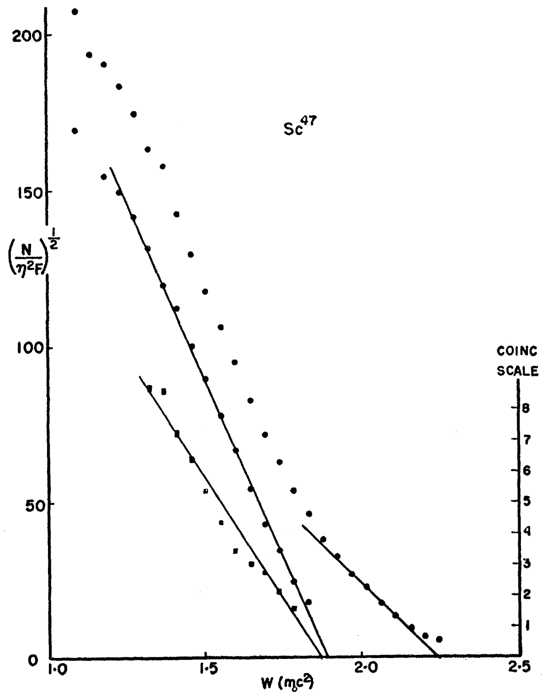

FIG. 1. Fermi plots for beta rays of Sc^{47}. ● Singles spectrum taken with scintillation spectrometer. ■ Coincidence spectrum; beta rays in coincidence with 159-kev line.

Cork, LeBlanc, Brice, and Nester[2] measured Sc^{47} using a permanent-field photographic spectrograph, a double-focusing spectrometer, and scintillation counters. They found a gamma ray whose energy is 0.1595 Mev and a beta ray of end-point energy 0.64 Mev, both attributed to Sc^{47}. A coincidence experiment, using a NaI crystal for gamma rays and an anthracene crystal and aluminum absorption for the beta rays, indicated that the 0.64-Mev group was in coincidence with the 0.160-Mev gamma ray. Marquez,[3] using a magnetic lens spectrometer, found beta-ray groups at 0.490 (72%) and 0.280 (28%) Mev with an indication of an internal conversion line corresponding to a gamma ray at 0.218 Mev. Lyon and Kahn[4] measured the gamma ray with a scintillation counter, obtaining a value of 0.157±0.007 Mev. Coincidences between beta rays, measured by a proportional counter using aluminum absorption, and gamma rays, measured by a scintillation spectrometer, showed that a group of energy 0.46±0.02 Mev was in coincidence with the gamma ray. The end point of the higher energy group is given as 0.62±0.03 Mev.

MEASUREMENTS

The separated isotope Ca^{44} was bombarded with 23-Mev alpha particles in the Indiana University cyclotron. Scandium was separated chemically from any other activities present. The source was aged to allow any Sc^{43}, produced from the small amount of Ca^{40} present in the source, to decay.

Several beta-ray sources were made up and examined with a magnetic lens spectrometer. Unfortunately, the specific activity was low and the sources in the beta-ray investigations were thicker than desirable, causing the Fermi plots to bend away at the low-energy end. Three separate experiments were performed, giving end points for the two groups of 0.600±0.002 and 0.439±0.002 Mev. Owing to the thickness of the sources it is not felt that the relative abundance measurements are reliable.

A thin source was then investigated with two scintillation spectrometers used in coincidence. The beta rays were measured with the help of an anthracene crystal and the gamma rays with a NaI(Tl) crystal. The resolving time of the coincidence circuit was 0.2 microsecond.

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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] L. Marquez, Phys. Rev. **92**, 1511 (1953).

[4] W. S. Lyon and B. Kahn, Phys. Rev. **99**, 728 (1955).

The beta-ray distribution of the singles spectrum was measured and a Fermi plot made of the results. This is shown in Fig. 1. The end points obtained for the two groups are 0.629±0.010 and 0.455±0.020 Mev. The relative abundances are approximately 40% and 60% respectively. The scintillation spectrometer measuring gamma rays was then set on the 0.159-Mev line and the distribution of the beta rays in coincidence with the gamma ray was measured. The Fermi plot of these data is also shown on Fig. 1. The end-point energy is 0.429±0.020 Mev. The lower energy beta-ray group is, therefore, in coincidence with the gamma ray. The calibration of the scintillation counter measuring beta rays was made in terms of the internal conversion line from Cs^{137} at 0.625 Mev.

The energy of the gamma ray was measured both in a scintillation spectrometer and a magnetic lens spectrometer. In the scintillation counter experiments, the energy of the gamma ray was found to be 158.5±2 kev, when calibrated against the line from Ce^{139} at 166 kev. With the lens spectrometer, experiments using both lead and uranium radiators were performed, yielding an energy of 158±2 kev. In order to check whether any other gamma rays were present which might be in coincidence with the line at 0.159-Mev, gamma-gamma coincidence experiments were performed in which one scintillation spectrometer was set on the 0.159-Mev line and the other swept through the spectrum. No gamma rays in coincidence with the one at 0.159 Mev were found.

TABLE I. Characteristics of the disintegration of Sc^{47}.

Beta-ray energy Mev	Relative abundance %	Log *ft*
0.600±0.002	40	6.0
0.439±0.002	60	5.2
Gamma-ray Energy Mev		
0.159±0.002		

Since the beta-ray sources were too weak for the measurement of internal conversion lines and none were found, it was decided to try to determine the half-life of the 0.159-Mev state. To do this, a coincidence experiment was carried out between beta rays of an appropriate energy and the 0.159-Mev gamma ray, using the scintillation spectrometers in coincidence. A variable-delay line was placed in the coincidence circuit so that the coincidences could be obtained in which the gamma ray was delayed with respect to the beta ray or vice versa. The results gave a curve indicative of a prompt transition. By comparing these results with a similar curve taken on[5] As^{71}, it is estimated that the half-life of the 0.159-Mev state is less than 4×10^{-8} sec.

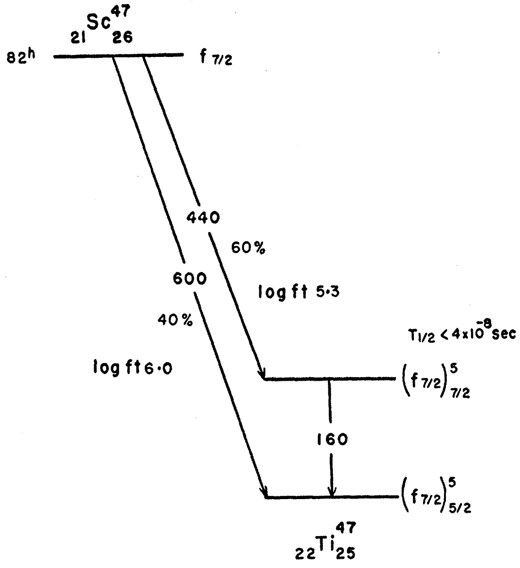

FIG. 2. Distintegration scheme of Sc^{47}.

Since the calculated half-life for an *M*1 transition is $\sim10^{-10}-10^{-11}$ sec and for an *E*2 transition is $\sim1\times10^{-7}$ sec, the present experiments would infer that the transition is mostly of an *M*1 character.

DISCUSSION

The results of these experiments are given in Table I. There are two beta-ray groups of energy 0.600±0.002 and 0.439±0.02 Mev and one gamma ray of energy 0.159 Mev. The lowest energy group is in coincidence with the lower energy beta-ray group. The data suggest the disintegration scheme shown in Fig. 2. The results are essentially in agreement with those of Lyon and Kahn.[4]

The ground state of the product, Ti^{47}, has a spin of 5/2 and a magnetic moment[6] of $-(0.78706)$ nm. According to the analysis of Kurath,[7] this can probably be explained by assuming that it is an $[(f_{7/2})^5]_{5/2}$ configuration. The first excited state is probably $[(f_{7/2})^5]_{7/2}$. The transition from the ground state of Sc^{47} to the first excited state of Ti^{47} has a log $ft=5.2$, indicating an allowed transition. Since Sc^{47}, with 21 protons, probably has a ground-state configuration of $f_{7/2}$, the assignments given to the ground state of Sc^{47} and the excited states of Ti^{47} are therefore consistent with the value of log *ft*. The higher value, log $ft=6.0$, for the transition to the ground state, indicates this transition is suppressed over what one would expect for a 7/2 to 5/2 transition with no change of parity.

The difference between the beta-ray transition probabilities to the ground state and to the excited state can be understood from shell-model considerations. The wave functions of the parent and product states may be

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[5] W. E. Graves and A. C. G. Mitchell, Phys. Rev. **97**, 1033 (1955).

[6] C. D. Jeffries, Phys. Rev. **92**, 1262 (1953).

[7] D. Kurath, Phys. Rev. **91**, 1430 (1953).

written:

$$\varphi_i(\text{Sc}^{47}) = [f_{7/2}{}^6(n)]_0 f_{7/2}(p),$$
$$\varphi_g(\text{Ti}^{47}) = [f_{7/2}{}^5(n)]_{5/2}[f_{7/2}{}^2(p)]_0,$$
$$\varphi_e(\text{Ti}^{47}) = [f_{7/2}{}^5(n)]_{7/2}[f_{7/2}{}^2(p)]_0.$$

Here φ_g and φ_e represent the wave functions for the ground state and excited state of Ti^{47}, respectively. If the calculation is carried out assuming that one of the neutron pairs of the parent is broken to form a proton pair in the product, it turns out that the transition to the excited state is allowed and that to the ground state is forbidden. On the other hand, if the ground-state configuration is used to calculate the magnetic moment of Ti^{47}, one obtains -1.67 instead of -0.787 nm. It is presumed that the "almost allowed" transition to the ground state (log $ft = 6.0$) has its explanation in a certain amount of configuration mixing in the ground state which is at the same time responsible for the low value of the magnetic moment.

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Alpha-Particle Bombardment of A^{36} and A^{40}†*

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Gas targets (130-kev thick) of natural argon (99.6% A^{40}; 0.34% A^{36}) and of argon enriched in A^{36} (97.4% A^{36}; 2.5% A^{40}) have been bombarded with 7.4-Mev alpha particles from the Yale cyclotron. Protons and neutrons at 90° to the incident beam have been studied by means of 50μ Ilford *C*-2 emulsions, placed 16 cm from the target. The ground-state *Q*-value for the $A^{36}(\alpha,p)K^{39}$ reaction is -1.28 Mev, with excited states at 2.50 and 2.87 Mev. The ground state *Q* for $A^{40}(\alpha,p)K^{43}$ is -3.36 Mev, with excited states at 0.65 and 1.18 Mev. The cross sections for these two reactions, as well as for the $A^{40}(\alpha,n)Ca^{43}$ reaction, have been measured and are found to be in general agreement with the predictions of simple compound-nucleus theory.

INTRODUCTION

In 1924, Rutherford and Chadwick[1] reported particles emitted from argon under alpha bombardment. This reaction was then reinvestigated by Pollard and Brasefield,[2] Buchanan,[3] and others using natural argon (99.6% A^{40}, 0.34% A^{36}) and argon considerably enriched in A^{36}. However, since no protons were ever observed in these later experiments, this is the only part of Rutherford's early work in this field which has not been verified by later, more exact, measurements. Our present work, then, in addition to obtaining *Q*-value information in the currently important region around $Z=20$, indicates why the earlier investigators failed to detect any protons from these reactions. The explanation lies in a combination of circumstances: (1) the difficulty in handling gas targets, (2) the low alpha-beam currents available, (3) the fact that the most abundant isotope (A^{40}) has a low cross section, (4) the negative *Q*-values for these reactions, resulting in low-energy protons which were difficult to detect.

ALPHA-PARTICLE BOMBARDMENT

Argon gas targets were bombarded with 7.4-Mev alpha particles from the Yale cyclotron. The target chamber had a 0.87-mg/cm² mylar entrance window, and a 6.9-mg/cm² aluminum exit window. The chamber was initially pumped down through the main cyclotron vacuum, and the argon was then admitted at 15 cm pressure, making a target about 130-kev thick. Two different targets were used: one was natural argon (99.6% A^{40}; 0.34% A^{36}) and the other was argon enriched to 97.4% A^{36}. The enriched sample had been previously prepared by Anderson[4] using thermal diffusion methods and the procedure described by Zucker and Watson.[5]

Protons and neutrons at 90° to the alpha beam were studied by means of 50μ Ilford *C*-2 emulsions placed 16 cm from the chamber. The plates were allowed to fade for about 12 hours after bombardment, then

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