in this experiment. It should be noted, however, that the earlier experiments yield, in general, still higher values for the stopping powers than are obtained from Thompson's I values and Eqs. (2) and (3). Some of these earlier results represent average values over the whole range of the particle rather than instantaneous values. The discrepancies in earlier results are the chief justification for the use of Thompson's accurate work as a standard of comparison in this experiment. It is of interest to note that if $I_{\mathrm{Al}}=170$ ev, following the suggestion of Sachs and Richardson,[9] a calculated value of $s=1.47$ is obtained, in good agreement with the results of this experiment. The fact that we have used relative stopping powers, however, does not give any additional support to the hypothesis of an energy-dependent I.[10]

Grateful acknowledgment is made to E. I. du Pont de Nemours and Company for providing the foil samples used. The authors are indebted to Mr. Edgar Hubbard for assistance with the calculations, and to Mr. Shaler Knowles for help in construction of the apparatus.

[9] D. C. Sachs and J. R. Richardson, Phys. Rev. **89**, 1163 (1953).

[10] See reference 4, p. 816.

PHYSICAL REVIEW VOLUME 95, NUMBER 2 JULY 15, 1954

Disintegration of K^{43}†

Torsten Lindqvist* and Allan C. G. Mitchell
Physics Department, Indiana University, Bloomington, Indiana
(Received March 26, 1954)

The nuclear spectrum of K^{43} (22.0 hr) has been studied with the help of a magnetic lens spectrograph. K^{43} decays to Ca^{43}, emitting gamma rays having energies 0.369, 0.627, 0.219, 0.393, and 1.00 Mev, the last three being weak. Five beta-ray groups were found, of energies 1.839, 1.218, 0.927, 0.460, and 0.243 Mev with relative abundance of 1.6, 5.4, 83.1, 5.4, and 4.5 percent, respectively. A disintegration scheme is proposed. The K^{43} was prepared by the reaction $A^{40}(\alpha,p)K^{43}$.

I. INTRODUCTION

OVERSTREET, Jacobson, and Stout[1] were the first to report on K^{43}. They bombarded argon gas with 40-Mev alpha particles. The argon was allowed to flow slowly through a 20-foot long gas chamber, connected to the cyclotron. They reported a half-life of 22.4 hr, two beta groups of energies 0.25 and 0.81 Mev measured in a magnetic spectrograph with permanent field and also by an absorption method, and a gamma ray of energy 0.4 Mev, measured by absorption in lead. Since no detailed information exists on the disintegration scheme of this isotope, it was decided to make a study of its radiations in a nuclear spectrograph.

In addition, the spin of the ground state of Ca^{43} has been measured to be 7/2, and the shell model would predict a state of $d_{3/2}$ for the ground state of K^{43}. The experiments of Overstreet, Jacobson, and Stout have been taken to imply that the transition from K^{43} to the ground state of Ca^{43} is allowed while from the shell model one would expect a transition characterized by $\Delta j=\pm 2$, yes. These considerations furnish an additional reason for making the investigation.

† Supported by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.

* On leave from Physics Department, University of Uppsala, Uppsala, Sweden.

[1] Overstreet, Jacobson, and Stout, Phys. Rev. **75**, 231 (1949).

II. PREPARATION OF SOURCES

The isotope K^{43} was prepared by the reaction $A^{40}(\alpha,p)K^{43}$. Argon gas from a commercial tank was put into a gas chamber of size 17 in.×4 in.×1½ in. Between the cyclotron tank and the gas chamber there was, in the first experiment, a 1-mil Al foil. The gas was bombarded by 22-Mev alpha particles in the Indiana University cyclotron. The major portion of the active potassium settled out on the walls of the chamber. Following the bombardment the chamber was washed with distilled water to give a solution of the active potassium. After the first run it was found that in addition to the 22-hr K^{43} there was also a small amount of the 12.4-hr K^{42}, obtained from the reaction $A^{40}(\alpha,pn)K^{42}$. In order to suppress this reaction, the beam was passed through two 2-mil copper foils, which reduced the beam energy by 4 to 5 Mev. Since the (α,pn) reaction decreases more rapidly with alpha-particle energy than does the (α,p) reaction, it was possible to suppress the K^{42} activity entirely with the result that only the 22-hr period was observed.

The chemical separation was carried out by the ion exchange column method.

The half-life was checked each time with a separate source and was found to be 22.0 hr.

III. THE GAMMA-RAY SPECTRUM

The gamma rays were investigated by measuring the distribution of photoelectrons from lead and uranium radiators with the help of a magnetic lens spectrometer. The surface density of the lead radiator was 8 mg/cm^2 and that of the uranium radiator 90 mg/cm^2. Figure 1 shows the distribution of the photoelectrons from the uranium radiator. Photoelectron lines corresponding to five gamma energies were found and are shown in Table I. The energies for γ_2, γ_3, and γ_4 were determined from the experiments using the lead radiator. The K and L photolines were well resolved except for the L_3 which was partly hidden under the L_2. The energies for γ_1 and γ_5 were determined using the uranium radiator (see Fig. 1), where the K and L lines for γ_1 are easily seen while only the K line for γ_5 is seen. The decay of the lines was followed and was found to be 22 hr. The 1-Mev line, too weak to furnish more than a rough estimate of the half-life in the beta spectrometer, was followed in a scintillation spectrometer and was also found to be of the same half-life. The relative intensities were determined from a run with the lead radiator using the photoelectron cross sections obtained from Gray's formula.[2]

TABLE I. Gamma rays from K^{43}.

Notation	Energy, Mev	Relative intensities
γ_1	0.219 ± 0.004	1
γ_2	0.369 ± 0.003	67
γ_3	0.393 ± 0.004	6
γ_4	0.627 ± 0.006	100
γ_5	$1.00\ \pm0.02$	4

TABLE II. Beta-ray groups of K^{43}.

Group	E Mev	Relative abundance %	$\log(ft)$	Spin and parity	Transition
I	1.839 ± 0.030	1.6	10.00[a]	$\Delta j=\pm2$, yes	First forbidden
II	1.218 ± 0.025	5.4	7.36	$\Delta j=\pm1,0$ yes	First forbidden
III	0.827 ± 0.020	83.1	5.54	$\Delta j=\pm1,0$ no	Allowed
IV	0.460 ± 0.020	5.4	5.87	$\Delta j=\pm1,0$ no	Allowed
V	0.243 ± 0.030	4.5	4.94	$\Delta j=\pm1,0$ no	Allowed

[a] $\text{Log}[(W_0^2-1)ft]$.

IV. THE BETA-RAY SPECTRUM

In order to investigate the distribution in energy of the electrons a thin source was prepared by dissolving the potassium in distilled water and allowing a drop of this solution to evaporate onto a thin Zapon foil. The GM counter used in the lens spectrometer was fitted with a thin window of stretched Teflon having a cutoff at about 10 kev.

The electron distribution was analyzed by making a Fermi plot of the data. The results are shown in Fig. 2. The spectrum can be analyzed into five groups. The results obtained are shown in Table II. The beta group of highest energy, Group I, was found to have a forbidden shape. The Fermi plot for this group was corrected by the forbidden shape factor $S_n(W)$, corresponding to a transition in which $\Delta j=\pm2$ and there is a change of parity,

$$S_n(W)=(W^2-1)+(W_0-W)^2=C_{IT}(W),$$

where W and W_0 are the energies and end-point energies, respectively. In addition the value of $\log[(W_0^2-1)ft]$ for this group was determined to be 10.0 from these experiments, which is just the value to be expected for this type of transition.

The decay was followed over the entire spectrum and was found to be 22 hr.

Internal conversion electrons were also looked for, but only the 0.627-Mev gamma ray showed a very weak line. The internal conversion coefficient for this

[2] L. H. Gray, Proc. Cambridge Phil. Soc. **27**, 103 (1931).

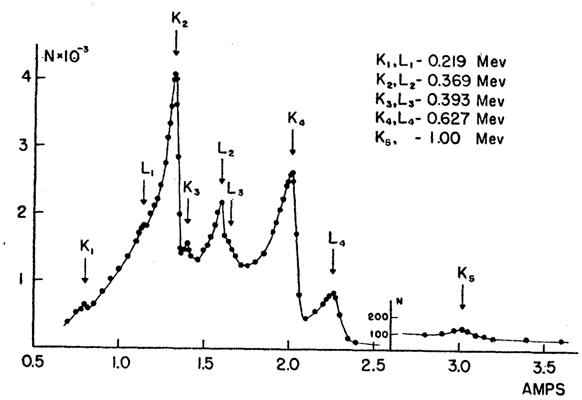

FIG. 1. Photoelectrons ejected by gamma rays of K^{43} from uranium radiator.

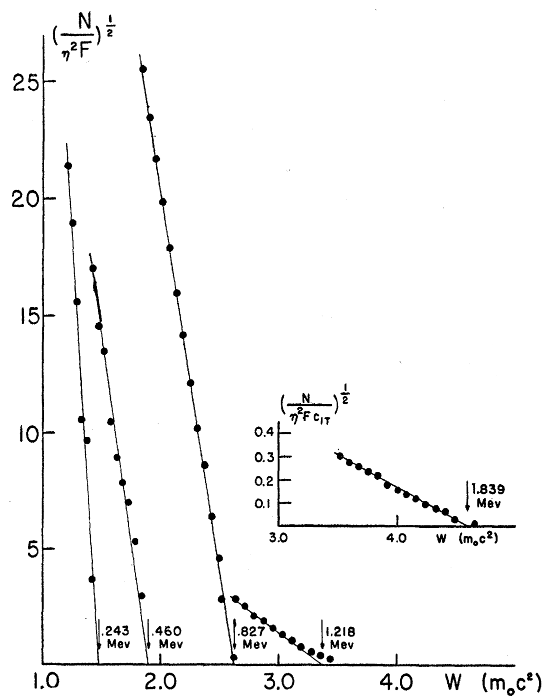

FIG. 2. Fermi plot of the beta rays of K^{43}.

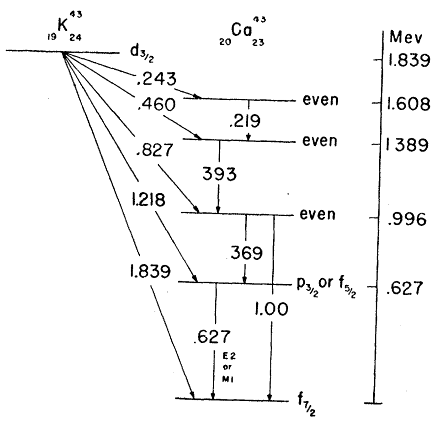

FIG. 3. Decay scheme of K^{43}.

gamma ray was estimated to be 2.10^{-4}, with a rather large error.

V. DISCUSSION

The decay scheme consists of five beta-ray groups together with five gamma rays which fit well into the scheme shown in Fig. 3. The highest energy beta-ray group shows a shape characteristic of a transition for which $\Delta j = \pm 2$, with a change of parity. Since the spin and magnetic moment of the ground state of Ca^{43} has been measured by Jeffries,[3] who gives a spin of 7/2 and a configuration $f_{7/2}$, the spin and parity of the ground state of K^{43} must be $\frac{3}{2}$ and even. Thus the experiments are in agreement with an assignment of $d_{3/2}$ to the ground state of K^{43}, as predicted by the shell model. Beta group II has a value of log $ft = 7.36$ suggesting that it has $\Delta j = \pm 1$, yes. Thus the first excited state of Ca^{43} could be $p_{1/2}$, $p_{3/2}$ or $f_{5/2}$.

The internal conversion coefficient for the gamma ray at 0.627 Mev was found to be 2×10^{-4}. From the tables of Rose, Goertzel, and Perry,[4] the values of the internal conversion coefficient in the K shell which agree most closely with the measured values are $E1$, 1.0×10^{-4}; $E2$, 3.1×10^{-4}; and $M1$, 1.7×10^{-4}. Taking into consideration the possible assignments from the beta-ray transition, the evidence from the internal conversion coefficient limits the assignments to $p_{3/2}$ and $f_{5/2}$ and makes the character of the 0.627-Mev gamma transition either $E2$ or $M1$. From the shell model point of view, one expects the states $p_{3/2}$ and $f_{5/2}$ to have approximately the same energy with a tendency for the $p_{3/2}$ state to be lower. It thus seems reasonable to assign the configuration $p_{3/2}$ to the 0.627-Mev state and $E2$ to the 0.627-Mev line as a first preference.

The main beta-ray group (Group III) is allowed. From this information the only reasonable assignments to the state at 0.996 Mev are $d_{5/2}$ and $d_{3/2}$. The transitions to the higher states are also allowed so that these states should have even parity and spins of $\frac{1}{2}$, $\frac{3}{2}$, or 5/2. Since internal conversion coefficients were not measured it is impossible to assign definite configurations to these states.

The present experiments give a determination of the total disintegration energy, namely 1.839 Mev. Haxel, Jensen, and Suess[5] have given curves for the total disintegration energy of radioactive isotopes having the same isotopic number $I = N - Z$ plotted against neutron number. The disintegration energy for K^{43} determined in this experiment fits very nicely onto

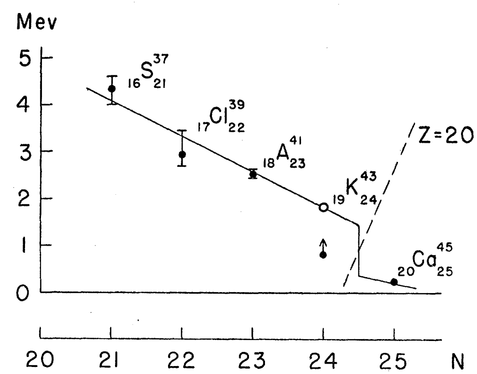

FIG. 4. Total disintegration energies in the neighborhood of $Z = 20$. The solid circles and the curve are taken from Haxel, Jensen, and Suess (reference 5). The open circle is the present result for K^{43}.

the curve for S^{37}, Cl^{39}, A^{41}, K^{43}, Ca^{45}, all having $I = 5$. This portion of the curve of Haxel, Jensen, and Suess is shown in Fig. 4. It will be noted that there is a sharp break in the disintegration energy curve at $Z = 20$, in agreement with shell model predictions. The point for K^{43} used by Haxel, Jensen, and Suess, obtained from older data, is shown for reference.

The authors are indebted to Dr. M. B. Sampson and the cyclotron group for making the bombardments and to Mr. Arthur Lessor for making the chemical separation. One of us (T.L.) wishes to acknowledge a grant from the Swedish Atomic Committee and a fellowship from the Sweden-America Foundation.

[3] C. D. Jeffries, Phys. Rev. **90**, 1130 (1953).

[4] Rose, Goertzel, and Perry, U. S. Atomic Energy Commission Report ORNL 1023, 1951 (unpublished).

[5] Haxel, Jensen, and Suess, Ergeb. exakt. Naturwiss. **26**, 244 (1952).