An explanation must also be given for the fact that no rotational level is found in the observed spectrum. With the above interpretation, the rotational level would be expected to have a spin of 11/2 (+). The transition to this state from the 7/2 (−) state would, therefore, also be predominantly of multipole order $M2$. The ratio, R_T, of the transition probabilities for the emission of a given multipole radiation from a state, i, to two different members, f and f', of a rotational family is given by[21]

$$R_T=\left[\frac{E}{E'}\right]^{2L+1}\frac{\langle I_i, L, K_i, K_f-K_i|I_i, L, I_f, K_f\rangle^2}{\langle I_i, L, K_i, K_f-K_i|I_i, L, I_{f'}, K_f\rangle^2}, \quad (2)$$

where E=energy of the emitted gamma ray, I=total angular momentum, L=multipole order, K=the component of I along the symmetry axis of the nucleus, and the bracketed quantities are the Clebsch-Gordan coefficients for the addition of angular momenta. For $L=2$ and for a rotational state of energy greater than 120 kev, the ratio of the transition probabilities is less than eight percent. It is improbable that such a weak transition could be observed in the presence of the background produced by the Compton scattering of the 366-kev γ rays.

[21] Alaga, Alder, Bohr, and Mottelson, Kgl. Danske Videnskab. Selskab, Mat.-fys. Medd. **29**, No. 9 (1955).

V. ACKNOWLEDGMENTS

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Decay of 2.7-Hour Sr^{92}†

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The decay of 2.7-hr Sr^{92}, produced as a fission product activity, has been studied using the scintillation method. Gamma rays of energy 0.23±0.02, 0.44±0.04, and 1.37±0.05 Mev were found, with relative intensities of 0.039±0.004, 0.045±0.004 and 1.00, respectively. Beta-ray spectrometry using anthracene and beta-gamma coincidence studies indicate a major beta of 0.545±0.05 Mev in coincidence with the 1.37-Mev gamma ray. Comparison with 4π beta measurements indicate a branching ratio of 90±10% leading to the 1.37-Mev excited state ($\log ft=4.3$).

I. INTRODUCTION

THE 2.7-hr fission product Sr^{92} activity has been reported by Götte,[1] who determined its half-life by observing the production of the 3.5-hr Y^{92} daughter activity from uranium fission. Since the time of these early measurements, no further information on the decay characteristics of this nuclide has appeared in the literature. Because of this lack of detailed information a study was undertaken to determine the decay scheme, using the scintillation method.

II. EXPERIMENT AND RESULTS

Source Preparation

Samples of short-lived strontium fission-product activity were prepared by making short-time irradiations of uranyl nitrate in a high-flux facility of the MTR. The strontium chemical fraction was then obtained and samples mounted for observation. Since 9.7-hr Sr^{91} was also present in the samples and the decay of the two strontium activities gives rise to 55-min Y^{91} and 3.5-hr Y^{92}, activity was observed with a minimum time delay following the chemical separation.

Gamma-Ray Measurements

The scintillation gamma detectors used were cylinders of NaI(Tl), 3 inches in diameter and 3 inches long, mounted on DuMont type 6363 photomultipliers mounted in the manner described by Lazar and Klema[2] to produce the conditions for good gamma ray spectroscopy. Sources were mounted 3 cm from the surface of the detector on the central axis and a 1.6-g/cm² polystyrene absorber used to remove the beta rays. The detector assembly was housed in a "graded" lead shield with inside dimensions of 12×12×24 inches. Pulse analysis was accomplished by using a 20-channel pulse sorter of the type designed by Bell, Kelley, and Goss,[3] operated in conjunction with a 100-channel automatic readout system designed at this laboratory.

Figure 1 shows the pulse spectrum of the gamma

† Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] H. Götte, Naturwiss. **28**, 496 (1941).

[2] N. H. Lazar and E. D. Klema, Phys. Rev. **98**, 710 (1955).
[3] Bell, Kelley, and Goss, Oak Ridge National Laboratory Report ORNL-1278, 1951 (unpublished).

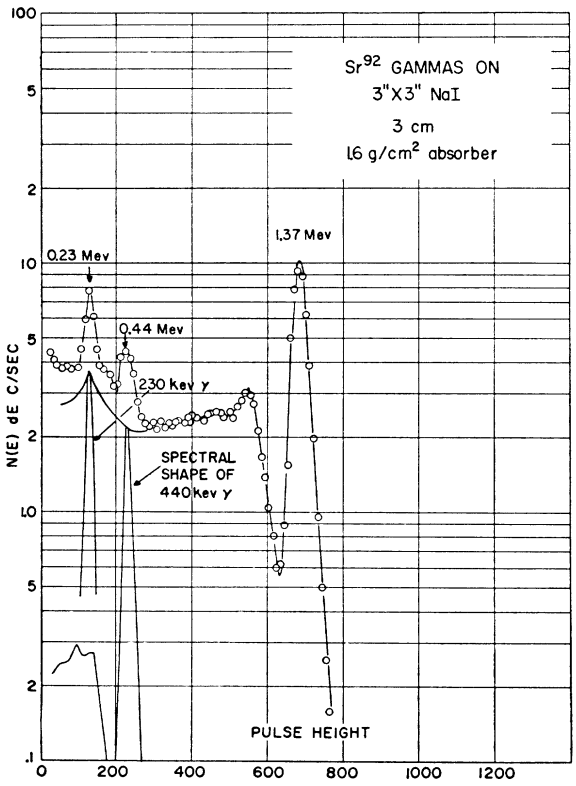

FIG. 1. Gamma-ray spectrum from Sr^{92} source observed 3 cm from NaI(Tl) crystal 3 inches in diameter and 3 inches long.

radiation identified with the decay of the 2.7-hr Sr^{92} activity and the analysis. This spectrum was obtained by subtraction of 9.7-hr Sr^{91} and the 55-min Y^{91} and 3.5-hr Y^{92} daughter activities present in the gross samples. The spectral "shapes" used for this purpose were obtained from samples of strontium and yttrium prepared from gross fission products and measured in the same geometrical configuration.

Repeated measurement of the gross spectrum of the strontium chemical fraction indicated that three principal gamma rays of energy 0.23 ± 0.02, 0.44 ± 0.04 and 1.37 ± 0.05 Mev all followed a decay period of 2.7 ± 0.2 hr. Energy calibration of the scintillation spectrometer was obtained by comparison with the 1.11-Mev gamma ray of Zn^{65} for the 1.37-Mev gamma ray and the 0.478-Mev gamma ray of Be^7 for the two lower energy gamma rays. These calibration sources were used as internal standards, measuring the standards and the Sr source simultaneously, in order to minimize the errors due to gain shift from variations in counting rate and spectral content.

The relative intensities of the gamma rays were obtained by successive subtraction of pulse-height distributions representing the response of the detector to monoenergetic radiation under the particular geometrical arrangement used in these measurements. The 0.23-Mev gamma of Te^{132}, the 0.478-Mev gamma of Be^7 and the 1.38-Mev gamma of Na^{24} were used for this purpose. Relative emission rates for the gamma rays were then determined by the well-established method of Bell *et al.*[4] This involves integration under the full-energy peak of the pulse-height distribution for each gamma ray and correction for the ratio of peak area to total area obtained by careful measurement of the response of the detector to monoenergetic radiation as a function of gamma-ray energy and source-detector configuration. Table I lists the measured gamma-ray energies, their relative intensities, and the values of the peak-to-total ratios used. The peak-to-total ratios were obtained from measurements in this laboratory and those of Bell *et al.*[5]

Beta-Ray Measurements

Beta-ray spectral measurements were obtained using a $1\frac{1}{2}$-inch diameter by $\frac{1}{4}$-inch anthracene detector covered with a 1-mg/cm^2 aluminized Mylar reflector. Sources were prepared on thin films of rubber hydrochloride with a total source thickness of less than 1 mg/cm^2. Energy calibration was achieved by comparison with the 0.625-Mev conversion line in Ba^{137m}.

Subtraction of the beta spectra of Sr^{91}, Y^{91}, and Y^{92} from the gross spectrum indicated one major beta ray of approximately 0.55-Mev energy which followed a 2.7-hr half-life. The spectra of the Sr and Y activities for subtraction were obtained from special sources prepared by chemical fractionation with a judicious choice of separation time to yield pure samples of these activities. Fermi analysis of a typical beta-ray spectrum of the Sr^{92} beta thus obtained is shown in Fig. 2. This analysis yields an end-point energy of 0.545 Mev. The observation of low-intensity beta groups of higher

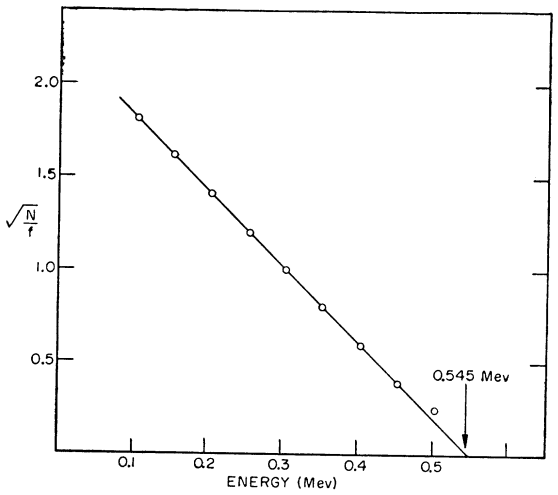

Fig. 2. Fermi plot of the Sr^{92} beta-ray spectrum.

[4] P. R. Bell, in *Beta- and Gamma-Ray Spectroscopy*, edited by K. Siegbahn (Interscience Publishers, Inc., New York, 1955), Chap. V.

[5] P. R. Bell (private communication).

energy was prohibited by the presence of the 3.5-Mev beta ray emitted in the decay of the 3.5-hr Y^{92} daughter activity and the high-energy betas associated with the decay of the 9.7-hr Sr^{92}.

Coincidence Measurements

To obtain beta-gamma coincidence spectra, a 3-inch by 3-inch NaI detector and the $1\frac{1}{2}$-inch by $\frac{1}{4}$-inch anthracene detector were mounted with their axis in a horizontal line and with a spacing of 4.0 cm between the detectors. A "graded" backscatter shield was used to reduce false-coincidence effects from scattering between the two detectors. Polystyrene absorbers were used between the source and the gamma detector to stop the beta radiation and between the beta detector and source for the purpose of determining the gamma-ray contribution by difference measurement. The coincidence circuit used was of the "fast-slow" type which permits coincidence pulse-height analysis ($2\tau = 5\times10^{-7}$ sec). The coincidence spectrometer consisted of an automatic sliding-window single-channel analyzer operated in coincidence with the 100-channel machine.

With the single-channel analyzer set to span the photoelectric peak of the 1.37-Mev gamma ray on the pulse distribution from the gamma detector, a spectrum of coincident beta radiation was obtained. A plot of this spectrum indicated only the presence of the 0.545-Mev beta ray. Likewise, observation of the gamma radiation in coincidence with the low-energy beta indicated only the presence of the 1.37-Mev gamma ray. No gamma radiation above the random background was observed coincident with beta radiation greater than 0.6 Mev. Gamma-gamma coincidence studies with two 3-inch $\times$3-inch NaI detectors mounted in a similar configuration gave no indication that either of the two low-energy gamma rays were coincident with one another or with the 1.37-Mev gamma ray.

For the purpose of determining the beta-ray branching ratio between the 1.37-Mev excited state and the ground state, comparison was made between the beta disintegration rate determined with a 4π flow proportional counter and the emission rate for the 1.37-Mev gamma ray. Sources were mounted on 0.1-mg/cm^2 rubber hydrochloride films and the decay of the total beta activity followed for a sufficient time to permit accurate subtraction of the 9.7-hr Sr^{91}, and the daughters—3.5-hr Y^{92} and 57-day Y^{91}. The corresponding emission rate for the 1.37-Mev gamma ray was determined by measurement with a 3-inch$\times$3-inch NaI detector, integrating under the photoelectric peak and correcting for peak-to-total area ratio, absorption in the beta shield, and detection efficiency for the geometry used. From these data a branching ratio of $90\pm10\%$ was obtained for beta transitions leading to the 1.37-Mev excited state.

TABLE I. Energies and intensities of Sr^{92} gamma rays.

Gamma-ray energy Mev	Intensity relative to 1.37-Mev gamma ray	Peak-to-total ratio used ($h=3$ cm)
0.23±0.02	0.039±0.004	0.93
0.44±0.04	0.045±0.004	0.65
1.37±0.05	1.00	0.33

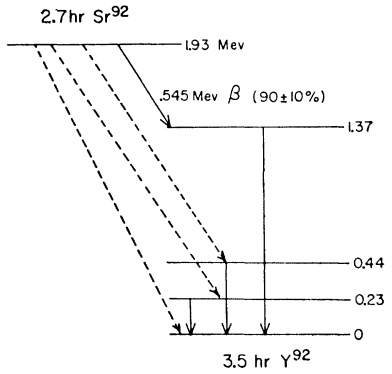

FIG. 3. Proposed decay scheme for Sr^{92}.

III. DISCUSSION

On the basis of the experimental observations discussed above, the tentative decay scheme shown in Fig. 3 is proposed for the major characteristics of the decay of 2.7-hr Sr^{92}. The value of logft for the 0.545-Mev beta ray, computed from the branching ratio, was found to be 4.3. If we assume an upper limit of 10% for the branching ratio of the ground state transition this yields a value of 7.1, indicating a first forbidden transition with a spin change of zero or one. The difficulty encountered in measuring the intensity of the ground state transition due to the presence of contaminant activities prevented any further interpretation in terms of the single-particle model. For this same reason we were unable to determine the origin of the two low-energy gamma-rays, their indicated position in the level scheme being dictated largely by the results of the coincidence studies.

IV. ACKNOWLEDGMENTS

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