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Decay Scheme of Sb^{124}

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The beta- and gamma-rays emitted by Sb^{124} (60d) have been investigated with the help of Geiger-counter coincidences. We find that the hard beta-ray of 2.4 Mev is followed by one gamma-ray, while the soft beta-ray of 0.7 Mev is followed by two gamma-rays. The intensity ratio of the hard to the soft beta-rays is found to be about 1:1.

INTRODUCTION

THE beta- and gamma-radiations of Sb^{124} have been studied by a number of investigators, but a few questions deserving further investigation remained. Mitchell, Langer, and McDaniel,[1] who studied these beta- and gamma-radiations by means of Geiger-counter coincidences, concluded that it decays with emission of a single β-ray of 1.54-Mev maximum energy, followed by a γ-ray of 1.82 Mev and probably a second γ-ray of ≤ 0.069 Mev. A lower value for the energy of the hard gamma-ray, namely, $1.75 \pm .04$ Mev was obtained by Klaiber and Scharff-Goldhaber,[2] based on a measurement of the energy of the photo-neutrons from $Sb^{124}+Be$ with a hydrogen-filled ionization chamber. From O'Neal's[3] work on the slowing down of photo-neutrons in water, a value of $1.73 \pm .04$ Mev can be deduced for the Sb^{124} γ-ray. Kruger and Ogle[4] determined the gamma-ray energy by observing electron pairs produced in a Wilson cloud chamber and found a value of $1.70 \pm .02$ Mev. Hales and Jordan[5] resolved the beta-rays with a magnetic spectrograph into two spectra of maximum energies $0.74 \pm .03$ and $2.45 \pm .07$ Mev. The energy difference of 1.71 Mev agrees fairly well with the average value for the gamma-ray energy. Hales and Jordan suggested, therefore, that Sb^{124} decays partly by emission of a "hard" beta-ray of 2.45 Mev and partly by emission of a "soft" beta-ray of 0.74 Mev followed by a 1.71-Mev gamma-ray. They left the possibility open that in both cases the 0.069-Mev gamma-ray observed by Mitchell, Langer, and McDaniel may follow in the end. Recently Miller and Curtiss,[6] also using a beta-spectrograph, obtained

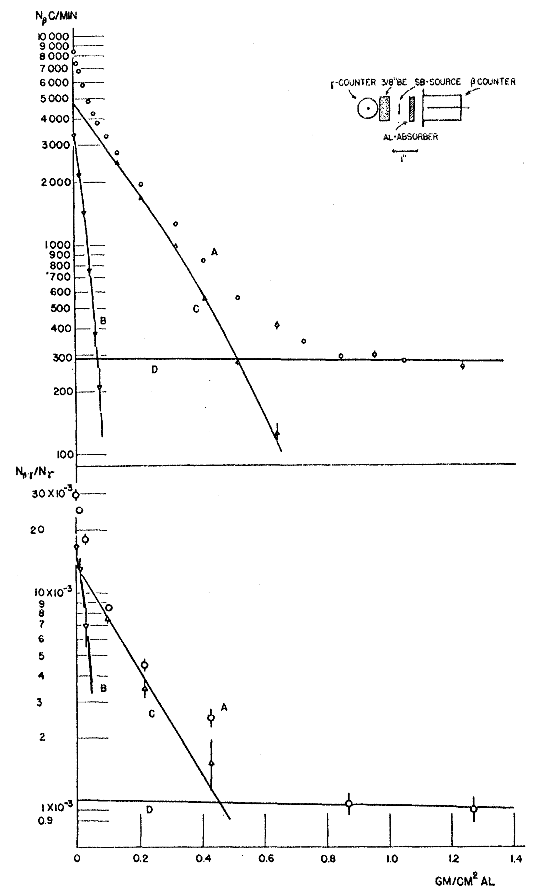

FIG. 1. Top: absorption of the radiation from Sb^{124} in Al. (*A*) measured points, (*B*) "soft" beta-rays, (*C*) "hard" beta-rays, (*D*) gamma-ray background (drawn using additional points beyond 1.4 g/cm² Al). Bottom: Absorption in Al of beta-gamma coincidences per recorded gamma-ray. (*A*) measured points, (*B*) coincidences with "soft" beta-rays, (*C*) coincidences with "hard" beta-rays, (*D*) gamma-gamma coincidences.

[1] A. C. G. Mitchell, L. M. Langer, and P. W. McDaniel, Phys. Rev. **57**, 1107 (1940).
[2] G. S. Klaiber and G. Scharff-Goldhaber, Phys. Rev. **61**, 733A (1942).
[3] R. D. O'Neal, Phys. Rev. **70**, 1 (1946).
[4] P. G. Kruger and W. E. Ogle, Phys. Rev. **67**, 273 (1945).
[5] E. B. Hales and E. B. Jordan, Phys. Rev. **64**, 202 (1943).
[6] L. C. Miller and L. F. Curtiss, Phys. Rev. **70**, 983 (1946).

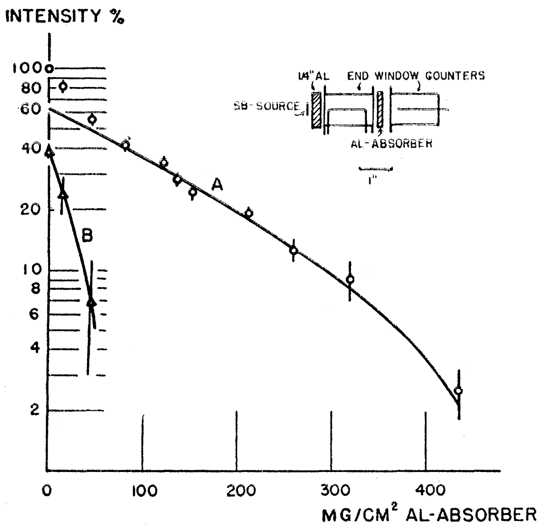

FIG. 2. Coincidence-absorption curve for the Compton electrons produced by the gamma-rays of Sb^{124}. The measured curve is analyzed into a hard component (A) and a soft component (B).

lower values for the beta-ray energies than Hales and Jordan, namely, 0.53 and 2.25 Mev, but the energy difference again agreed closely with the gamma-ray energy.

EXPERIMENTAL METHODS

In order to test more explicitly the decay scheme suggested by Hales and Jordan, we carried out β-γ and γ-γ coincidence measurements with Sb^{124}. This source was obtained by bombarding antimony with 10-Mev deuterons followed by chemical purification. Our coincidence circuit had a resolving time of 1 μsec. The beta-rays were detected with a mica-window counter, the mica having a thickness of 4 mg/cm². For the detection of the gamma-rays a Geiger counter with a cylindrical gold electrode was used. A beryllium block was placed in front of this counter to filter out the beta-radiation. Schematic drawings added to the figures indicate the arrangement used for each type of measurement.

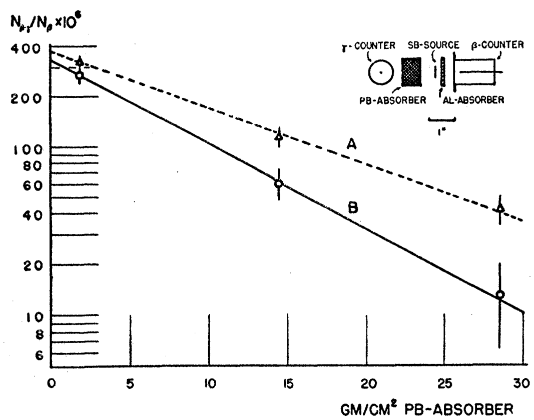

FIG. 3. Beta-gamma coincidences as function of gamma-ray absorber thickness. (A) No absorber between source and beta-ray counter. (B) 82 mg/cm² Al between source and beta-ray counter.

RESULTS

The absorption of the beta-rays in aluminum was first studied. An analysis of the absorption curve (Fig. 1, top, curve A) shows two distinct β-ray components (curves B and C) corresponding to the soft and hard beta-rays found with the magnetic spectrograph. The intensity ratio of the hard beta-rays to soft beta-rays was 1.0 ± 0.2. To obtain this figure a correction for the mica-window thickness (4 mg/cm²) and the thickness of the source (15 mg/cm²) was applied. Curve D represents the gamma-ray background.

We next studied the beta-gamma coincidences for the two beta-ray components (Fig. 1, bottom) with the result that both coincide with gamma-rays. The coincidence rates found were 1.3×10^{-3} per soft beta-ray and 0.68×10^{-3} per hard beta-ray, i.e., approximately in the ratio 2:1. We can understand this result if we assume that the hard beta-ray is followed by a single gamma-ray, (γ_1), and that the soft beta-ray is followed by two gamma-rays (γ_2 and γ_1).

We first believed[7] that γ_1 and γ_2 were of comparable energy, since we were unable to see any structure in a lead absorption curve taken in "poor" geometry. Drs. Miller, Curtiss, and Feister then drew our attention to the fact that a gamma-ray of 0.61 Mev, which was possibly identical with γ_1, was reported by Rall and Wilkinson[8] and tentatively ascribed to $Te^{122,124?}$ (30 d ?).*

By measuring the energy of the Compton electrons produced in Al by the gamma-rays from Sb^{124}, using the method of coincidence absorption,

[7] W. E. Meyerhof and Gertrude Scharff-Goldhaber, Bull. Am. Phys. Soc. May 1947, Washington meeting.

[8] W. Rall and R. G. Wilkinson, Phys. Rev. **71**, 321 (1947).

* *Note added in proof:* Drs. Curtiss and Feister have kindly informed us that the 0.6-Mev γ-ray decays with a 60 d half-life.

we confirmed the presence of two gamma-rays of approximately 1.7 and 0.6 Mev (see Fig. 2). This conclusion was reached by analyzing the absorption curve according to Bleuler and Zünti's method.[9] For the measurement, one counter with mica windows on both ends and a conventional mica end-window counter were used, as sketched in Fig. 2. In our previous coincidence absorption measurements, for which two Eck and Krebs counters had been used, the 0.6-Mev component could not be detected.

Figure 3 shows the result of beta-gamma coincidence measurements for varying thicknesses of the gamma-ray absorber. Curve A was measured with no absorber between source and beta-ray counter, while for curve B 82 mg/cm^2 Al were interposed, which absorbed the soft beta-rays. The slope of curve B, corresponding to a half-value thickness of 6 g/cm^2 Pb, is compatible with a gamma-ray energy of 0.6 Mev. Curve A has a half-value thickness of 8.5 g/cm^2 Pb, corresponding to a "weighted" average of the 0.6- and 1.7-Mev gamma-rays.

TABLE I.

β_1(Mev)	β_2(Mev)	γ(Mev)	Method
1.54		1.82 $\leqslant$.069	Absorption in Al and Pb, reference 1.
		1.75±.04	Photo-neutrons* detected by proton recoils, reference 2.
		1.73±.04	Slowing down of photo-neutrons* in water, reference 3.
		1.70±.02	Electron pairs observed in Wilson chamber, reference 4.
		1.72±.03	Photoelectrons. Magnetic lens spectrometer, reference 8.
2.45±.07	0.74±.03		Semicircular magnetic spectrograph, reference 5.
2.25	0.53		Magnetic lens spectrometer, reference 6.
		1.67	Photo-neutrons (n-p scattering cross section), reference†
		1.67	Photo-neutrons detected by proportional counter, reference‡

† A. Wattenberg, Phys. Rev. **71**, 497 (1947).
‡ A. O. Hanson, private communication.

[9] E. Bleuler and W. Zünti, Helv. Phys. Acta **19**, 375 (1946).

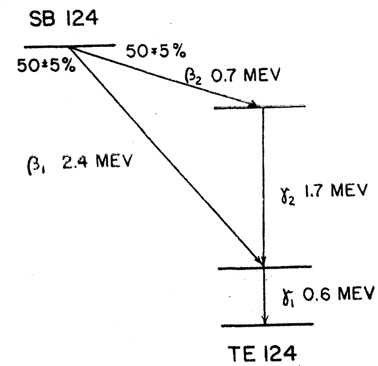

FIG. 4. Proposed decay scheme for Sb^{124}.

From these results it can be concluded that the 2.4-Mev beta-ray coincides with the 0.6-Mev gamma-ray, while the 0.7-Mev beta-ray coincides with the 1.7-Mev gamma-ray and the 0.6-Mev gamma-ray.

As we were unable to detect a gamma-ray of <0.069 Mev, the decay scheme of Hales and Jordan was modified as shown in Fig. 4.

The energies of the beta- and gamma-radiations of Sb^{124}, as obtained by the various investigators, are summarized in Table I.

ACKNOWLEDGMENTS

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