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Coincidence Experiments in Antimony 124

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The radiations from Sb^{124} (60 d.) have been measured with the help of coincidence counting methods. The beta-ray absorption curve was measured and analyzed by the method of Bleuler and Zünti. Two groups of electrons were found with end points at 2.24 and 0.51 Mev. Gamma-gamma and beta-gamma coincidences were measured. A plot of the number of beta-gamma coincidences per recorded beta-particle indicates that the spectrum is complex. Two low energy groups were found with end points at 0.75 and 0.47 Mev.

1. INTRODUCTION

COINCIDENCE counting techniques have been employed on several occasions to study the radiations from Sb^{124} (60 d.). The first attempt was made by Mitchell, Langer, and McDaniel,[1] who measured gamma-gamma and beta-gamma coincidences in this element. Later Meyerhoff and Scharff-Goldhaber,[2] Wiedenbeck and Chu,[3] and Scherb and Mandeville,[4] made a reinvestigation of Sb^{124} and found results somewhat different from those originally obtained by MLM. In order to clear up the differences between the earlier work of MLM and that of MSG, the authors have repeated some coincidence experiments in Sb^{124} as a part of a program carried on in this laboratory designed to work out in more detail the disintegration scheme of Sb^{124}. The other papers, dealing with the determination of gamma-ray and beta-ray energies will be found in this issue of the Physical Review.

2. APPARATUS

An end-window counter, having a window thickness of 6 mg/cm² of mica, was used to count beta-particles. To improve the efficiency[5] for counting gamma-rays, especially those with energy under one Mev, a cylindrical, lead cathode counter was used. During the experiment the source was situated between the two counters, 4.5 cm from the window of the beta-ray counter and 4.0 cm from the central axis of the gamma-

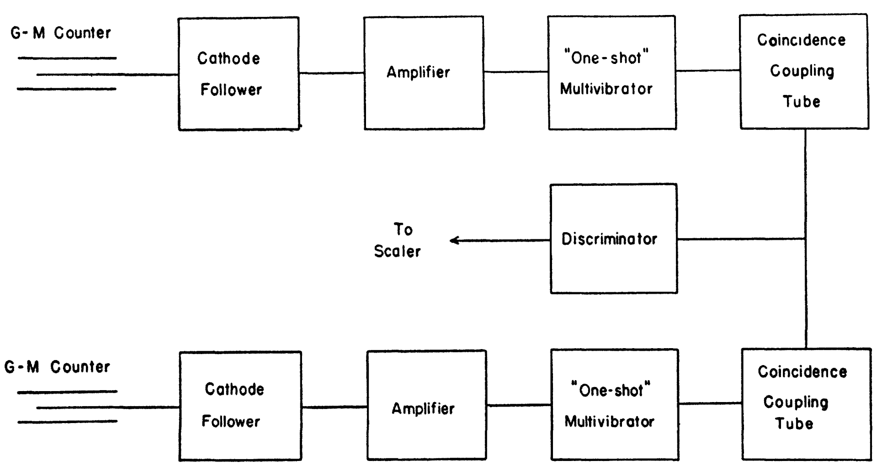

FIG. 1. Block diagram of the coincidence counting apparatus.

[1] A. C. G. Mitchell, L. M. Langer, and P. W. McDaniel, Phys. Rev. **57**, 1107 (1940), herein referred to as MLM.
[2] W. E. Meyerhoff and G. Scharff-Goldhaber, Phys. Rev. **72**, 273 (1947), herein referred to as MSG.
[3] M. L. Wiedenbeck and K. Y. Chu, Phys. Rev. **72**, 1164 (1947).
[4] M. V. Scherb and C. E. Mandeville, Bull. Am. Phys. Soc. **23**, No. 2, 40 (1948).
[5] H. Bradt, P. C. Gugelot, O. Huber, H. Medicus, P. Preiswerk, and P. Scherrer, Helv. Phys. Acta **19**, 77 (1946).

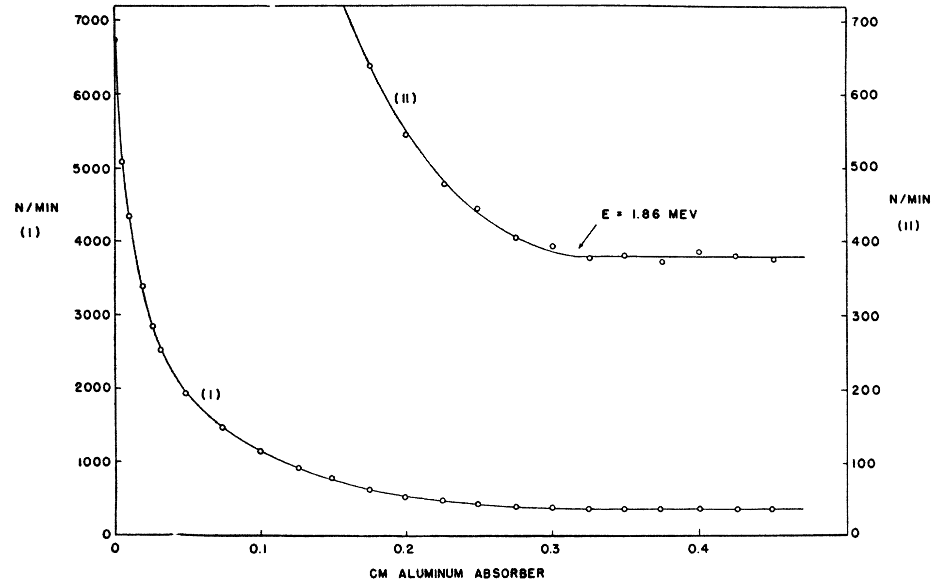

FIG. 2. Absorption of Sb^{124} beta-rays in aluminum.

ray counter. This type of arrangement is essentially that used by other investigators.[1-4]

A block diagram of the coincidence amplifier is shown in Fig. 1. The bias setting on the final discriminator tube can be adjusted for counting either coincidental pulses from both counters or for counting the individual pulses from a single counter.

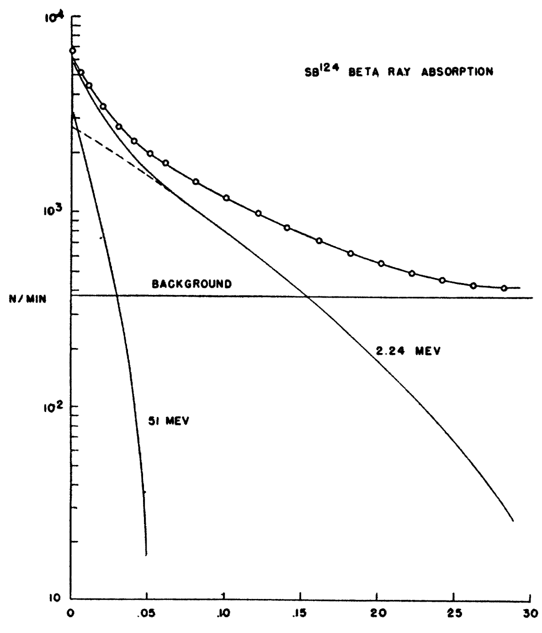

FIG. 3. Logarithmic plot of the beta-ray intensity as a function of aluminum absorber thickness.

The pulses which are applied to the grids of the Rossi-type coincidence circuit are formed by a "one-shot" multivibrator in each channel. This procedure insures a constant resolving time, independent of pulse height from the counters. The resolving time was determined from the usual relation

$$N_{ch} = 2n_1n_2t,$$

which gives the rate of chance coincidences as a function of individual counting rates in two counters which are counting particles from independent sources when the circuit resolving time is t. The resolving time was found to remain constant at 4.5 microseconds over a period of about three months.

3. RESULTS

Using the thin window counter and a thin source (under 10 mg/cm^2) mounted on Scotch tape, an absorption curve was run on the beta-rays. Figure 2 shows the usual method of plotting absorption curves, in which the number of counts per min. is plotted against the thickness of absorber. The "inspection" end point appears to be at 0.86 g/cm^2 corresponding to a range of 1.86 Mev. This value is much lower than the end points determined with the help of beta-ray spectrographs,[6] but is somewhat higher than that determined originally by MLM or that obtained later by Scherb and Mandeville.

If one makes an analysis of these data by the method of Bleuler and Zünti,[7] the beta-ray spectrum can be resolved into two groups with end points at 2.24 Mev and 0.51 Mev. Figure 3 shows the data plotted with log$R$ as ordinate (R = number of counts/min.) against the thickness of aluminum as abscissa. The circles show the experimental points. After the gamma-ray background is subtracted, the remaining curve can be broken down into two components. The relative abundance of the two groups is approximately equal, with the lower energy group showing a slightly higher abundance. Actually, the beta-ray spectrum consists of five groups,[6] with energies at 2.37, 1.62, 1.00, 0.65, and 0.48 Mev. The three higher energy groups comprise about 35 percent of the total intensity and the two lower energy groups about 65 percent. The end point for the lower energy component as obtained from the Bleuler and Zünti analysis probably represents the two high intensity, low energy groups. The fact that the "inspection" end point is much too low is clearly caused by the low intensity of the high energy groups.

Coincidence experiments were carried out in the usual way using, however, the lead lined counter as the gamma-ray counter and the thin window counter as the beta-ray counter. The gamma-gamma coincidence rate was obtained by placing an aluminum absorber 0.45 cm thick between the source and the beta-ray counter. This thickness is sufficient to stop all beta-particles. After corrections for cosmic-ray and chance coincidences, the gamma-gamma coincidence rate was determined. This rate can be referred either to the counting rate in the gamma-ray counter or to the gamma-ray counting rate in the beta-ray counter; that is, in the lead lined counter or the end window counter. The values were found to be $(N_{\gamma\gamma}/N_\gamma)_{\text{gamma}} = 0.29 \pm 0.017 \times 10^{-3}$ and $(N_{\gamma\gamma}/N_\gamma)_{\text{beta}} = 0.87 \pm 0.05 \times 10^{-3}$. Since the lead lined counter is more efficient for counting gamma-rays, the single count in this counter for a given source strength is higher than that in the end-window type, which accounts for the difference in the observed $N_{\gamma\gamma}/N_\gamma$ ratio. Naturally, the values of these ratios should not agree with any values found in previous experiments in which different types of counters were used. Since the efficiency of neither the lead lined nor the end-window type counter has been measured, the ratios $N_{\gamma\gamma}/N_\gamma$ will not be used in the calculation.

The number of beta-gamma coincidences was next investigated. To this end, the absorber thickness between the source and the end-window counter was varied, and the number of beta-

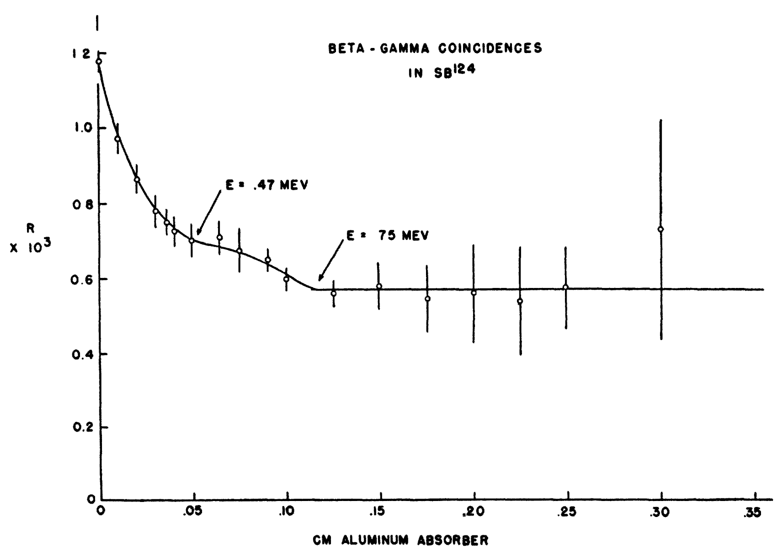

FIG. 4. Number of beta-gamma coincidences per recorded beta-ray as a function of beta-ray absorber thickness.

[6] See the preceeding papers in this issue.
[7] E. Bleuler and W. Zünti, Helv. Phys. Acta **19**, 375 (1946).

gamma coincidences determined. Figure 4 shows a plot of $R = N_{\beta\gamma}/N_\beta$, the number of beta-gamma coincidences per recorded beta-particle as a function of the absorber thickness. From this graph it will be seen that, beyond a thickness of 0.12 cm Al (the range corresponding to beta-rays of 0.75-Mev energy) the curve is parallel to the axis. Below 0.12 cm the curve rises and there is an additional sharp break at 0.05 cm of aluminum, corresponding to a beta-particle energy of 0.47 Mev.

One would infer from Fig. 4 that there are at least three groups of electrons and that there are more gamma-rays associated with the lower energy groups than with the high energy ones. These experiments are in good agreement with the tentative energy level scheme which has been proposed as a result of the investigation of the beta- and gamma-ray spectrum in the magnetic lens.[8] One of the high intensity groups as proposed by these authors has an end point of 0.65 Mev. The first break in the $N_{\beta\gamma}/N_\beta$ curve comes at 0.75 Mev which is in reasonable agreement with the magnetic lens data. In addition, another group appears at 0.47 Mev, which is just at the position of the second break in the coincidence curve. Since the high energy part of the beta-ray spectrum, beyond 1 Mev contains very few electrons, it is difficult to measure coincidences in the neighborhood of the end point, 2.37 Mev. It cannot, therefore, be definitely inferred from these experiments that the highest energy group does or does not lead to the ground state of Te^{124}.

The work reported in this paper is essentially in agreement with that of MSG, with the exception that an additional low energy group has been found here. The work of MLM failed to detect any low energy groups, probably because the counters used at that time had walls which were too thick to transmit those groups. In conclusion, the authors would like to point out that, for an element with a decay scheme as complicated as that of Sb^{124}, it is not possible to work out a detailed disintegration scheme on the basis of coincidence experiments alone.

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[8] See preceding paper by Kern, Zaffarano, and Mitchell.

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X-Ray Yield Curves for $\gamma - n$ Reactions

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Yield curves for the reactions $C^{12}(\gamma,n)C^{11}$ and $Cu^{63}(\gamma,n)Cu^{62}$ have been taken with x-rays up to 100 Mev. The induced radioactivity at each energy is plotted per unit x-ray intensity as measured by a r-meter thimble jacketed by $\frac{1}{8}$ in. of Pb. Both yield curves are similar to the photo-fission yield curves, the x-ray yield increasing to a maximum and then slowly decreasing as the x-ray energy is increased. With simple assumptions regarding the generation of ionizing secondaries in the Pb walls of the monitor and assumption of a constant intensity x-ray spectrum, these curves can be analyzed. The relative cross section is found to have a maximum at approximately 22 Mev for Cu^{62} and 30 Mev for C^{11}, decreasing to negligible values at high quantum energies. This decrease in cross section can be attributed to competition from multiple disintegrations. These reactions provide detectors sensitive only to part of the x-ray spectrum. Absorption curves have been taken in Pb using uranium photo-fission and in Cu and Pb using the $Cu^{63}(\gamma,n)Cu^{62}$ reaction as detectors. The resulting absorption coefficients compare favorably with theoretical values.

1. INTRODUCTION

INVESTIGATIONS which can be made with high energy quanta include measurements of cross section for photo-nuclear processes as a function of the energy of the absorbed quantum. In studying such processes with continuous x-rays generated by an electron accelerator, one

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