Energies of the Beta- and Gamma-Rays from Antimony

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The radiations from antimony bombarded by slow neutrons have been investigated in a large, high resolution, shaped-field magnetic spectrometer. The beta-spectrum of Sb^{124} (60 d.) was measured with a relatively thin source and with a thin window counter. The spectrum is found to be complex. By means of the Fermi theory, it is possible to resolve the distribution into at least five groups having the following end points and intensities: 2.37 Mev, 21 percent; 1.50 Mev, 7 percent; 0.98 Mev, 7 percent; 0.68 Mev, 26 percent; 0.50 Mev, 39 percent.

An internal conversion line was detected corresponding to a gamma-ray of 0.121 Mev.

Measurements on the Compton and photoelectrons ejected from a thin Pb radiator yield additional gamma-ray energies of 0.608, 0.654, 0.732, 1.708, and 2.04 Mev.

Measurements made while the short period activity was still present indicate that a gamma-ray of 0.568 Mev is associated with the 2.8-day activity of Sb^{122}.

I. INTRODUCTION

Since there appeared to be considerable disagreement among the results obtained by previous measurements for the energies of the radiations from Sb^{124} (60 d), it was thought desirable to reinvestigate the problem with the aid of a new, high resolution, shaped-field magnetic spectrometer. A similar investigation was undertaken simultaneously and independently at this laboratory by Kern, Zaffarano, and Mitchell, using a thin magnetic lens. Their results are reported in another paper in this journal. That paper gives a detailed discussion of the background of the problem and refers to the pertinent literature. The general agreement in the measurements made with these two instruments gives additional assurance of the accuracy of the results. The apparent complexity of the disintegration process in Sb^{124} makes more understandable the disagreement among the previous results obtained by low resolution methods.

II. EXPERIMENTAL METHOD

The magnetic spectrometer used for these measurements is described in detail elsewhere,[1] and has been used recently for the precise determination of the shape of the beta-spectra of Cu^{64}.[2] The instrument employs a radially inhomogeneous magnetic field in order to obtain higher order focusing at 180° from the source. The nominal value of the radius of curvature is 40 cm. When used with a thin source 0.4 cm wide, the full width at half-maximum for an internal conversion line is 0.5 percent. The instrument is free from spurious scattering effects.

The source used in these measurements was obtained by neutron bombardment of antimony metal in the Oak Ridge pile.

Sources for the measurement of gamma-ray energies were prepared by inserting the sample in a copper box whose front face was covered by a thin Pb radiator 0.4 cm wide by 2.5 cm high and 26.3 mg/cm² thick. The thickness of the copper walls of the box was chosen so as to prevent any nuclear beta-rays from escaping. The momentum of the photoelectrons and Compton electrons ejected from the Pb by the gamma-rays were measured in the spectrometer.

The source for the measurement of the beta-spectrum was prepared by electroplating a thin deposit of Sb less than 1 mg/cm² thick onto a 0.010-in. graphite backing. Distortion of the distribution caused by a source and backing of such thickness should be negligible for almost the entire spectrum.

For the region below $H\rho = 2500$ gauss-cm the beta-particles were detected by an end window G-M counter having a Zapon lacquer window with an electron range of 2.0 kev. For the upper end of the spectrum, and for the gamma-ray measurements, a mica window counter of 2.83 mg/cm² was employed.

[1] L. M. Langer and C. S. Cook, Rev. Sci. Inst. **19**, 257 (1948).
[2] C. S. Cook and L. M. Langer, Phys. Rev. **73**, 601 (1948).

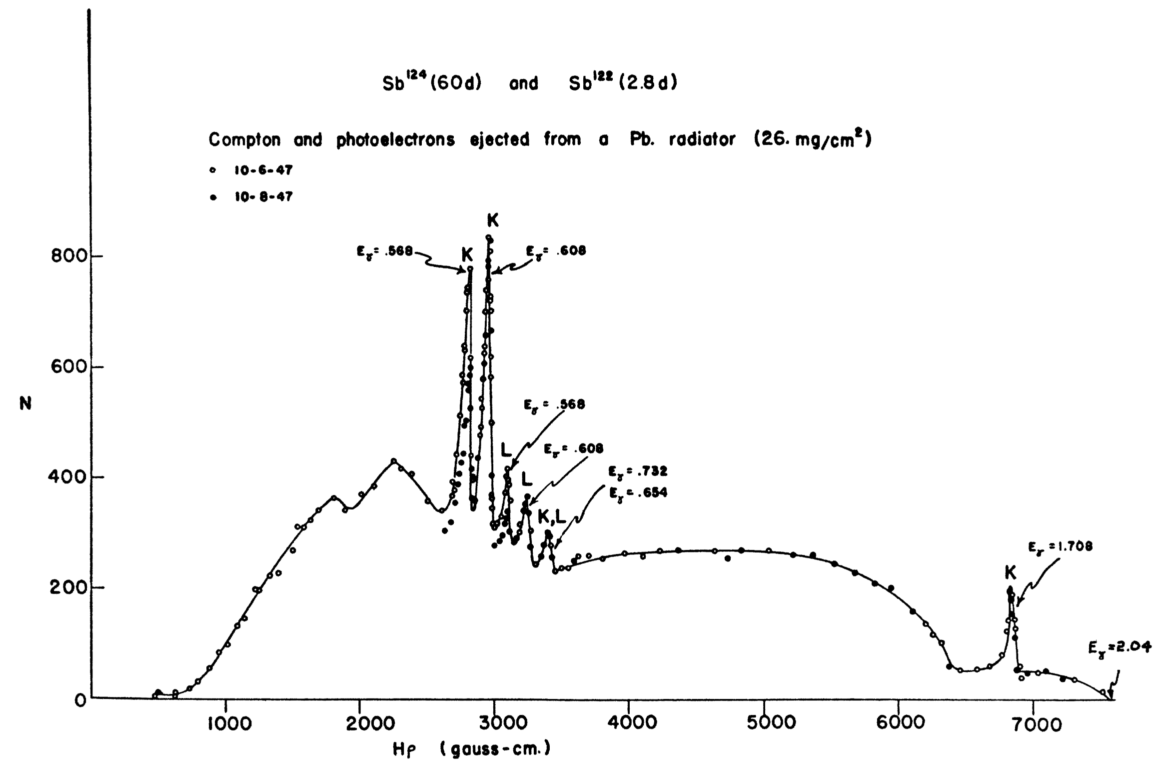

FIG. 1. Compton and photoelectrons ejected from a 26.3-mg/cm² Pb radiator by the gamma-rays of Sb^{124} and Sb^{122}. The number of counts detected is plotted against the momentum. The data represented by the solid circles were taken after a lapse of two days and show the decay of the K and L lines due to the 2.8-day Sb^{122}.

Relative measurements of magnetic field strength were made by means of a flip coil and ballistic galvanometer. The absolute calibration of the instrument is in terms of the 0.5108-Mev radiation from the annihilation of Cu^{64} positrons.

Whenever possible, the energies of gamma-rays are determined from the steep back edge of the K lines. Because of the multiplicity of the L levels, the back edge of these lines is not so clearly defined.

III. RESULTS

Figure 1 shows the momentum distribution of Compton and photoelectrons obtained from the Sb source just after it was received from Oak Ridge. The number of counts per minute are plotted against the momentum. The solid circles are for data taken after a lapse of two days and clearly identify the K and L lines of a gamma-ray of 0.568 Mev with the 2.8-day activity of Sb^{122}.

Associated with the 60-day Sb^{124}, photo lines are shown corresponding to gamma-ray energies of 0.608, 0.732, 0.654, and 1.708 Mev. In addition, the high energy Compton edge corresponds to a gamma-ray of 2.04 Mev. The superposition of the K line corresponding to the 0.732-Mev gamma-ray and the L line for the 0.654-Mev gamma-ray is more clearly shown in Fig. 2. This run was taken after the short period activity had died out and after chemical separation, particularly from any possible tin or tellurium impurities. Here the K line corresponding to the 0.654-Mev gamma-ray is clearly resolved.

Figure 3 shows the distribution of the beta-rays of Sb^{124} obtained with a chemically separated source and after all short period activities had died out. Here the number of counts, normalized by dividing by $H\rho$, is plotted against the momentum. From this curve it is obvious that the spectrum is complex and consists of at least two groups. In addition, a line of conversion electrons is observed having an energy of 89 kev. If these electrons are from the K level of tellurium, then they correspond to an Sb^{124} gamma-ray of 121 kev.

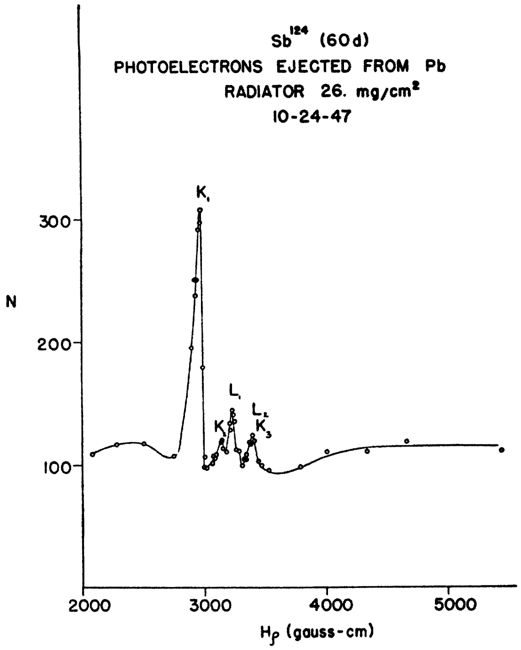

FIG. 2. Compton and photoelectrons ejected from a 26.3-mg/cm² Pb radiator by the gamma-rays of Sb^{124}. The source was chemically separated and all 2.8-day activity had died out.

If one assumes that the Fermi theory correctly describes the distribution of the beta-particles and if one assumes that on a Kurie plot[3] the component spectra should be straight lines, then one can resolve the complex experimental spectrum into five groups. The results of such an analysis are shown in Fig. 4. The maximum energies and the relative intensities of the five components are also shown. The validity for performing such an analysis is somewhat questionable in this case, inasmuch as some of the groups would belong to the so-called second forbidden class and do not necessarily have to follow straight line Kurie plots. Because of the number of subtractions involved, the values for the end-point energies of the inner groups are probably not good to better than 5 percent.

The Fermi plot for the lowest energy group does not yield a perfect straight line, but curves gently up at low energies. The *possibility* of a sixth low energy group is therefore not excluded. It would, however, be meaningless to try to resolve such a group by means of this analysis, for the following reasons: (a) there are indications that the Fermi theory may not be correct at low energies;[2] (b) the thickness of the source and backing may be introducing some distortion; (c) with additional subtractions, the errors multiply and the statistics become poorer at low energies.

IV. CONCLUSION

The disintegration of Sb^{124} has been observed to be quite complex. The beta-spectrum consists of at least two groups and may very well be

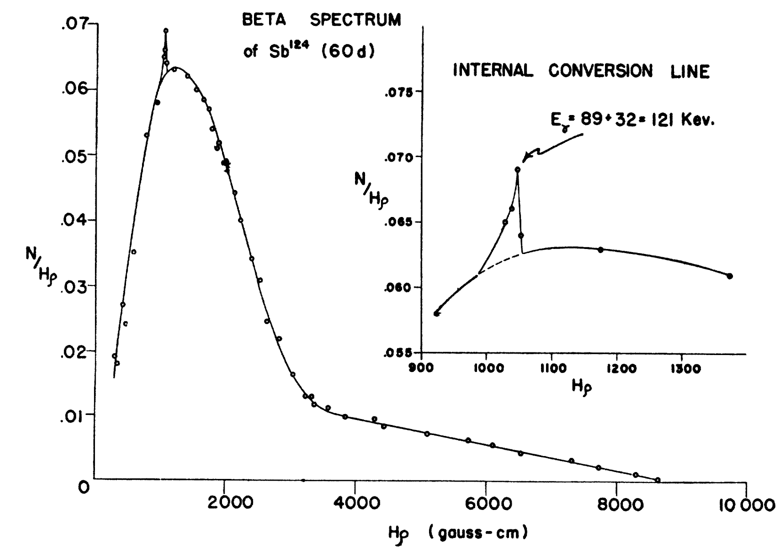

FIG. 3. Beta-spectrum of Sb^{124}.

[3] F. N. D. Kurie, J. R. Richardson, and H. C. Paxton, Phys. Rev. 48, 167 (1935).

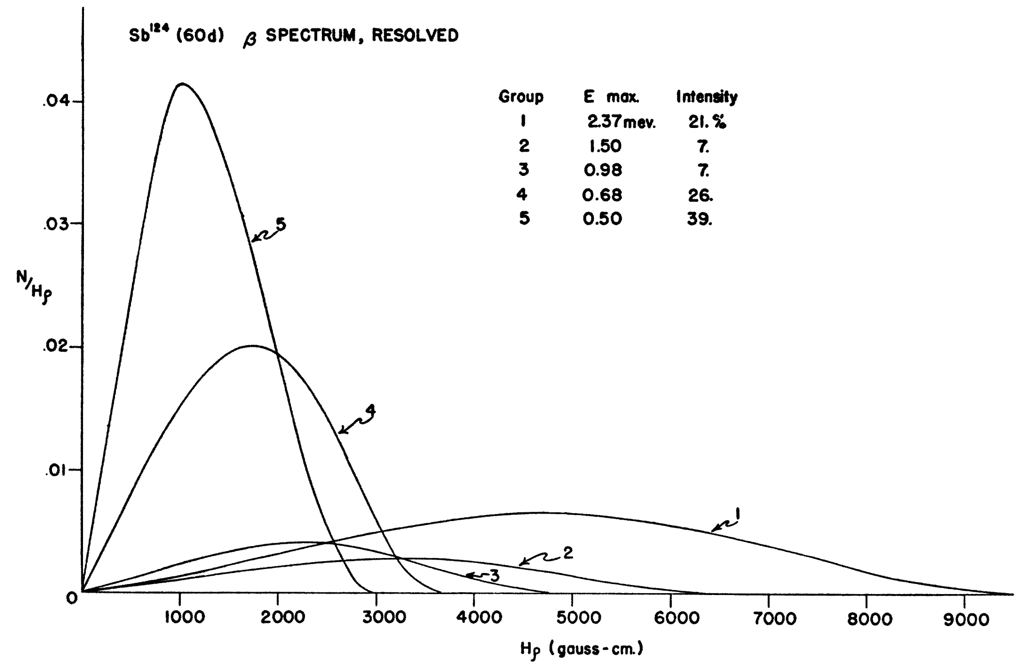

FIG. 4. The complex beta-spectrum of Sb^{124} resolved into five groups by means of the Fermi theory.

composed of five or six groups. The energies of six gamma-rays accompanying the disintegration of Sb^{124} have been measured.

An attempt can be made to fit the present data into a consistent energy level scheme. It is felt, however, that the data are still not sufficiently complete to ensure the uniqueness of such a scheme. Additional weak gamma-rays and low energy conversion lines may exist which would not have been observed in the present investigation because of the high resolution employed and because of the strength of the source. It is also possible that one or more of the gamma-rays which have been observed may be associated with a *K* capture process and therefore be characteristic of the levels of tin rather than those of tellurium. It is probable that only by beta-gamma coincidences in a spectrometer could one be completely certain of which gamma-ray follows which beta-particle group.

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