The Beta-Ray Spectrum of Tl^{206}

D. E. Alburger and G. Friedlander
*Brookhaven National Laboratory, Upton, Long Island, New York**
(Received April 25, 1951)

THE beta-decay of 4.23-minute Tl^{206} has been studied because of its relationship to previously reported work[1] on Bi^{206} and Po^{210}. All three of these nuclides decay to Pb^{206}, and it therefore seemed worthwhile to determine whether any of the excited states of Pb^{206} are involved in Tl^{206} decay. Previous work[2] with absorption methods indicated that Tl^{206} emits beta-rays of about 1.7-Mev maximum energy and no gamma-rays.

Samples of pure thallium metal were irradiated in the Brookhaven nuclear reactor and a beta-activity of 4.3±0.1-min half-life was observed. A search for gamma-radiation from strong sources was made with a scintillation spectrometer by photographing the pulse height distribution presented on an oscilloscope screen. These photographs revealed no gamma-ray structure, other than a continuum of energies mostly below 500 kev which can be accounted for only as bremsstrahlung from the beta-rays.

A lens spectrometer set for 3 percent resolution was used to study in detail the electron spectrum from evaporated foils of thallium metal approximately 2 mg/cm² thick. The foils were activated in the reactor for 5 minutes and delivered in a "rabbit" through the pneumatic tube system to an outlet near the spectrometer. A monitor counter, arranged to detect beta-rays directly from the source, allowed the counting interval to be matched to the source strength, thereby removing the effect of source decay.

In a search for gamma-rays no internal conversion lines were found. The Kurie plot of the beta-spectrum is shown in Fig. 1. Relativistic Fermi functions from Feister's table[3] were used in the calculations, and calibration was taken from the conversion line of Cs^{137}. The plot is linear above about 0.6 Mev and has an end point at 1.51±0.01 Mev. The deviation from linearity is about what one would expect from the source thickness and does not contradict the conclusion that the spectrum is simple and of the allowed type.

The result is in general agreement with an analysis of the internally converted gamma-rays of Bi^{206} and Po^{210} by Goldhaber and Sunyar,[4] according to which the first excited state of Pb^{206} at 803 kev is assigned a spin of 3 and odd parity. Since the decay of Tl^{206} to the ground state of Pb^{206} is allowed and therefore involves

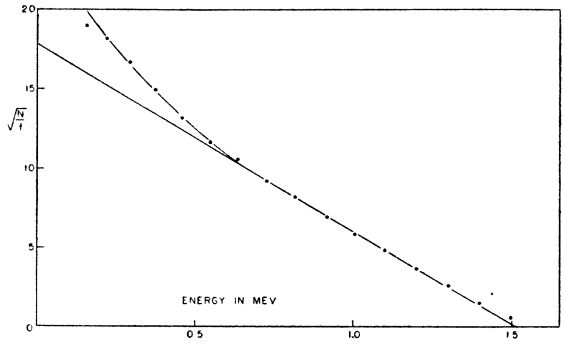

FIG. 1. Kurie plot of the Tl^{206} beta-ray spectrum.

a small nuclear spin change, one would expect that partial beta-decay to the first excited state is forbidden. Further analysis has not been possible, because the complete level scheme of Pb^{206} is not yet established.

We wish to thank Dr. H. T. Motz and E. der Mateosian for making their laboratory facilities at the reactor available for this work and Mr. A. Weinstein for preparing the evaporated thallium samples.

* Research carried out under contract with the AEC.
[1] D. E. Alburger and G. Friedlander, Phys. Rev. **81**, 523 (1951).
[2] Way, Fano, Scott, and Thew, Natl. Bur. Standards (U. S.) Circ. 499.
[3] I. Feister, Phys. Rev. **75**, 375 (1950).
[4] We are indebted to Drs. Goldhaber and Sunyar for making their unpublished results known to us.

The Combination of Resistivities in Semiconductors*

V. A. Johnson and K. Lark-Horovitz
Purdue University, Lafayette, Indiana
(Received April 25, 1951)

THE analysis[1] of resistivity *vs* reciprocal temperature curves for semiconductors, particularly germanium alloys, has shown that the experimental resistivity may be explained as due to a combination of a resistivity ρ_L due to the scattering of carriers by lattice ions and a resistivity ρ_I due to scattering by impurity ions; a complete analysis must also consider scattering processes due to neutral impurity atoms,[2] grain boundaries between crystallites, and the presence of ionized impurity centers of both signs.[3] Shockley and Schottky in discussions have first pointed out that the total resistivity is not given by the arithmetic sum of the partial resistivities;[4] more recently this fact has been discussed by Jones.[5] The following discussion of the proper combination of ρ_L and ρ_I corrects errors in Fig. 1 and Eq. (6) of reference 4 and also points out that our original argument[6] for obtaining higher mobility values from observed data is modified only slightly by this correction.

If one assumes that the two scattering processes are approximately independent of each other, the effective mean free path is given by

$$1/l=1/l_L+1/l_I, \tag{1}$$

where l_L and l_I are the mean free paths associated with lattice and impurity scattering separately. If one assumes the Rutherford scattering model[7] for evaluating ρ_I, the resistivity when only impurity scattering is present, then l_I is proportional to the fourth power of the velocity. Let ρ_L represent resistivity due to lattice scattering alone, with ρ_I negligible. With both lattice and impurity scattering present, the use of Eq. (1) in the usual expression for the resistivity of semiconductors leads to the following relation between the sum $\rho_L+\rho_I$ and ρ, the total resistivity:

$$F=(\rho_L+\rho_I)/\rho=(1+b^2/6)\left\{1-b^2\int_0^\infty xe^{-x}(x^2+b^2)^{-1}dx\right\}, \tag{2}$$

where $b^2=6\rho_I/\rho_L$. Figure 1 shows the dependence of the ratio F upon the fraction $\rho_I/(\rho_L+\rho_I)$. By private communication, we have learned that Shockley had previously calculated this function and obtained results identical with those of Fig. 1.

By using Eq. (1) in the calculation of the Hall coefficient R, one obtains the following relation [equivalent to Jones' Eq. (3)]:

$$r=R/(1/ne)=(\pi^{1/2}/48)(b^2+6)^2F^{-2}\int_0^\infty x^{9/2}e^{-x}(b^2+x^2)^{-2}dx. \tag{3}$$

The dependence of r upon $\rho_I/(\rho_L+\rho_I)$ is shown in Fig. 2. The abscissas in Jones' figure are values of ρ_I/ρ; if allowance for this difference is made, it is found that our curve and that of Jones are in substantial agreement. The figure is also consistent with Shockley's proof that $r\geqslant 1$.

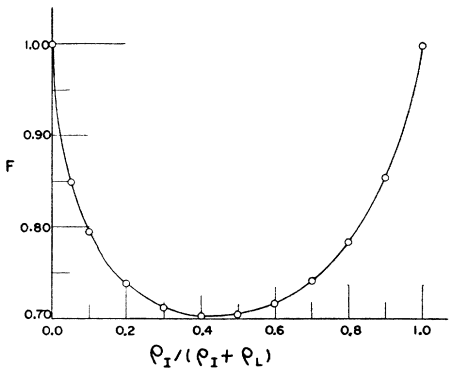

FIG. 1. The dependence of $F=(\rho_I+\rho_L)/\rho$ upon the ratio $\rho_I/(\rho_I+\rho_L)$.