incident proton beam, which is estimated to have a total spread of less than 4 Mev.

Miss Dora Sherman and Mr. Edwin Iloff have assisted in scanning the plates.

* This work was sponsored by the AEC.

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[2] K. Brueckner (private communication).
[3] W. Barkas, Phys. Rev. **75**, 1109 (1949).
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The Beta-Spectrum of Sn^{125}

RAYMOND W. HAYWARD
Department of Physics, University of California, Berkeley, California
May 29, 1950

THE beta-spectrum of the 9.9-day tin activity has been examined in a magnetic lens spectrometer similar to the one described by Siegbahn.[1]

Ketelle, Nelson, and Boyd[2] identified this tin activity as Sn^{125} by irradiating tin samples electromagnetically enriched in Sn^{124} with a high flux of slow neutrons. They were able to milk chemically the 2.7-yr. Sb^{125} activity from the activated tin sample on successive occasions.

A sample of the 9.9-day tin made by fission of thorium by deuterons and chemically separated with 50μg of carrier was furnished by Dr. A. S. Newton. A source was prepared by mounting the sample on a Nylon film supported by a Lucite ring so that the mass of the source was about 0.4 mg/cm^2. A beta-spectrum was obtained and a Fermi plot of the data is shown in Fig. 1. Forgetting for the moment the low energy component, there is the characteristic non-linearity associated with the type of forbidden spectrum in which a spin change of two units and a parity change occur in the transition. In this type of transition it is theoretically appropriate to modify the conventional Fermi plot by dividing the ordinate by a factor $(p^2+q^2)^{\frac{1}{2}}$ where p and q are the momenta of the electron and the neutrino, respectively. When this is done, we obtain the modified Fermi plot shown in Fig. 2 where the linearity indicates the correctness in assuming the interaction to be of the first-forbidden type. The end-point energy from this modified Fermi plot is 2.37±0.02 Mev which is slightly higher than that obtained by Ketelle *et al.* The $f\tau_{\frac{1}{2}}$-value of 3.7×10^8 is in experimental agreement with the other known beta-spectra exhibiting this type of forbidden shape.[3]

The low energy beta-component accounts for about five percent of the total intensity and has an upper energy limit of 0.40±0.01 Mev. From the preceding facts the presence of a gamma-ray of about 2 Mev energy and five percent intensity would be suspected. Efforts to find this gamma-ray by observation of the Compton

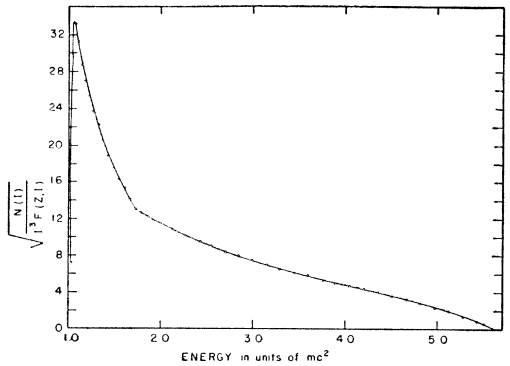

FIG. 1. A conventional Fermi plot of the Sn^{125} beta-spectrum in which only the density of final states for the beta-particle and the neutrino and the perturbation by the Coulomb field of the nucleus on the beta-particle are taken into account.

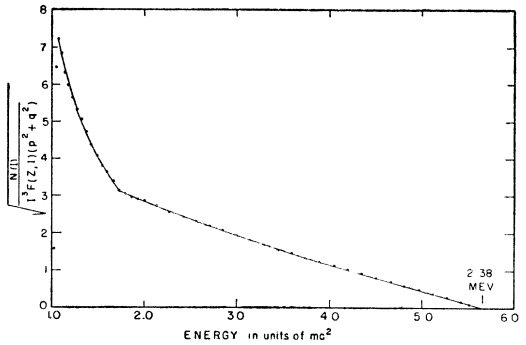

FIG. 2. A modified Fermi plot of the Sn^{125} beta-spectrum in which an additional factor $(p^2+q^2)^{\frac{1}{2}}$ is included, taking into account the dependence of the nuclear matrix elements on the momenta of the beta-particle and the neutrino.

electrons from a copper radiator surrounding a source of Sn^{125} in the spectrometer proved negative, but this could have been due to insufficient activity and the low branching ratio. However, absorption measurements in lead by Newton and McDonell[4] indicate the possible presence of a gamma-ray of about 1.5 Mev which could be the 2-Mev gamma-ray since absorption measurements in this energy range are inherently inaccurate when the intensity is low.

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[2] Ketelle, Nelson, and Boyd, Bul. Phys. Rev. **79**, 242 (1950).
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Electronic Mobility in Germanium*

V. A. JOHNSON AND K. LARK-HOROVITZ
Purdue University, Lafayette, Indiana
May 25, 1950

SOME time agao we analyzed the resistivity behavior[1] of a large number of germanium samples, prepared by adding varying amounts of various elements to high purity germanium. We found that it is possible to account for the observed resistivity from near the melting point down to very low temperatures as the sum of a lattice resistivity ρ_L due to scattering of carriers by lattice ions and an impurity resistivity ρ_I due to the Rutherford scattering of carriers by impurity ions.[2] The mobility associated with ρ_L is characteristic of the germanium lattice and so should be the same, at a given temperature, for all N-type germanium samples.

In our original analysis we used the classical expression for the Hall coefficient, $R=-3\pi/(8ne)$, where R is given in cm^3/coulomb, e in coulombs, and the electron density n in cm^{-3}. Hence the mobility was calculated from $b_L=8|R|/(3\pi\rho_L)$. Such computations yielded a room temperature electron mobility of 1450±300 cm^2/volt-sec. The samples in this group were polycrystalline and of low resistivity material (0.005 to 0.5 ohm-cm). More recently, measurements[3] have been made on samples of very high purity, usually single crystals. Analysis of the data for such samples usually has led to mobility values far higher than those previously obtained. In addition, Pearson, Haynes, and Shockley[4] have found that the mobility measured from drift velocities is constant, the same from sample to sample, but having a value considerably higher than that calculated by the use of $b=8|R|/(3\pi\rho)$.

In the hope of explaining these mobility discrepancies we have re-examined[5] the classical Hall coefficient expression and found that the numerical coefficient should be replaced by a variable quantity whose value is dependent upon the fraction of the total resistivity due to impurity scattering. This modification arises because the classical expression is based on the assumption that the mean free path of a conduction electron is independent of its kinetic energy; such is the case for lattice scattering except at very

TABLE I. Electronic mobilities in Ge at 300°K.

Nature of samples	Mobility in cm²/volt-sec.
Polycrystalline	3200±750
Single crystals	3370±550
Resistivity above 1.0 ohm-cm	3330±230
Resistivity below 0.1 ohm-cm	3250±790
All	3270±700

low temperatures, but impurity scattering is primarily Rutherford scattering with the mean free path proportional to the fourth power of the velocity. If the Hall coefficient is represented by $R=-r/(ne)$, the quantity r depends upon ρ_I/ρ in the manner shown in Fig. 1 of reference 5. The mobility is now calculated from $b_L=|R|/(r\rho_L)$. Table I shows the room temperature electron mobility, associated with lattice scattering, as obtained in the manner just described. The measure of error for the averages in Table I is given by the standard deviations of the respective data. The large deviations are due primarily to the uncertainty in the determination of the probe separations used in the resistivity measurements. In conclusion, it should be noted that, (1) the average mobility calculated in the manner described is in agreement with the "drift" and "conductivity" mobilities measured by Pearson *et al.*, (2) there is no significant difference in mobility between polycrystalline and single crystal samples, and (3) there is no significant difference in mobility between high and low resistivity samples.

* Work assisted in part by Signal Corps contract.

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[3] G. L. Pearson, Phys. Rev. **76**, 179 (1949); R. E. Davis and K. Lark-Horovitz, Progress Report of Purdue University Department of Physics to Signal Corps (August 1, 1948), p. 77; R. Bray, Progress Report (August 1, 1948), p. 86; C. S. Hung and J. R. Gliessman, Progress Report (December 1, 1949), p. 36.
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Spectrometer and Coincidence Studies on Np^{238}

M. S. FREEDMAN, A. H. JAFFEY, AND F. WAGNER, JR.
Argonne National Laboratory, Chicago, Illinois
May 1, 1950

THE Np^{238} used in these experiments was prepared by pile irradiation of Np^{237}, and subsequently separated from other activities and foreign salts. Spectrometer samples (~0.03 mg/cm²) were mounted on conducting LC-600 films. An anthracene scintillation detector was used, and the double-lens spectrometer resolution was three percent.

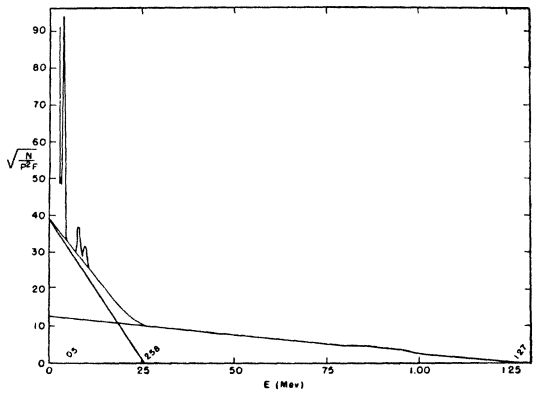

FIG. 1. Kurie plot of Np^{238} beta-spectrum. The Kurie plot of the low energy beta-component ($E_0=0.258$ Mev) can be seen at the left.

TABLE I. Radiations of Np^{238}.

Radiation	Energy[a] (Mev)	Binding energy of conversion electron (Mev)	Gamma-energy (Mev)	Abundance of conv. electron (rel. to weak β) (percent)	Conv. coef.[b] (percent)
β	0.258			100	
β	1.272			89	
Conv. elec.	0.913	0.124(K)	1.04	0.6	1.2
Conv. elec.	0.859	0.124(K)	0.98	0.6	1.2
Conv. elec.	0.0979	0.0048(M)	0.1028	2.2	4.7
Conv. elec.	0.0802	0.0222(L)	0.1029	3.5	7.5
Conv. elec.	0.0419	0.0048(M)	0.0467	6.0	12
Conv. elec.	0.0374	0.0048(M)	0.0422	27	27
Conv. elec.	0.0247	0.0222(L)	0.0469	37	74
Conv. elec.	0.0208	0.0222(L)	0.0430	71	71
Numerous conversion lines below 20 kev are also observed.					
Photo-electron	1.010	0.020(L)	1.030		
Photo-electron	0.966	0.020(L)	0.986		
Photo-electron	0.914	0.116(K)	1.030[c]		
Photo-electron	0.867	0.116(K)	0.983[c]		

[a] Calibration based on K conversion line of Au^{198}.
[b] According to decay scheme of Fig. 2.
[c] Gamma-energy taken from these values.

Table I summarizes the radiations observed. Photo-electron peak shift corrections were negligible for the 3.7-mg/cm² uranium radiator.[1] We estimate the 1.030 gamma to have 1.02 times the intensity of the 0.983 gamma. L and M binding energies for plutonium were obtained from a Moseley law extrapolation from the heavy element region. The Kurie plot, calculated with a relativistic Coulomb function, and by neglecting shielding, appears in Fig. 1. The transitions are seen to be both of the allowed shape, though the higher energy beta is empirically second forbidden ($ft=2.26\times10^8$). The lower beta is empirically allowed ($ft=1.03\times10^6$). The relative beta-intensities are consistent with these ft-values and with the relative beta-energies. For similarly high Z (79) the linear shape has been observed even for second-forbidden transitions.[2]

Gammas of low energy were sought with 30-mg/cm² uranium radiators and 5-mg/cm² gold radiators without success. By using a spiral baffle in the spectrometer together with an intense (100μC) beta-source, positrons were looked for, and an upper limit on the ratio of $\beta^+/\beta^-=0.001$ in the energy range above 50 kev was established. No x-ray or conversion line corresponding to K-capture was observed, contrary to predictions.[3] Using proportional counters, coincidences were found between (1) soft beta and L x-rays, (2) hard beta and L x-rays, (3) L x-rays and L x-rays, (4) soft beta and hard gamma, and (5) L x-rays and hard gamma. Measurements by D. Engelkemeir of this laboratory with anthracene scintillation counters showed coincidences between the hard beta and a quantum radiation of about 100 kev. A more precise half-life value, 2.10±0.01 days, was determined.

A tenatative decay scheme is suggested in Fig. 2.

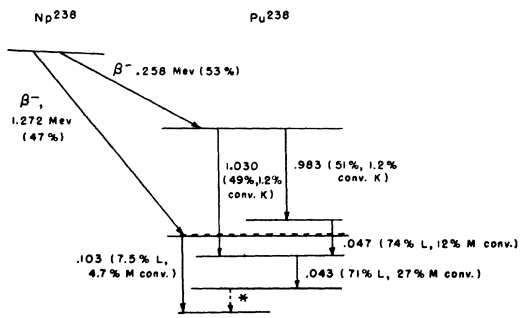

FIG. 2. Suggested decay scheme for Np^{238}. The transition marked * may be a 44-kev gamma whose conversion lines are unresolved from those of the 43-kev gamma; a 13-kev gamma if the dotted level is identical with that about it; or a 60-kev gamma (unlikely) if the dotted level is identical with that immediately below it.