Letters to the Editor

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Mass-Spectrographic Identification of Cm^{243} and Cm^{244}

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September 7, 1950

THE isotopes Cm^{243} and Cm^{244} have been identified mass-spectrographically. The curium fraction from a long neutron irradiation of Am^{241} was separated chemically and its isotopic composition determined by means of the 60° focusing mass spectrograph used in this laboratory for work with radioactive isotopes. A thermal ion source was used and the ions were recorded photographically. Figure 1 is a reproduction of the plate obtained.

The Am^{241} which is responsible for the rather intense line at mass 241 and the much fainter line at mass 257 ($Am^{241}O^+$) represents a very small fraction of the initial Am^{241} target material that was not successfully separated in the chemistry. The line at mass 254 is due to $Pu^{238}O^+$ which grew in from the alpha-decay of Cm^{242} after the chemical separation. The Cm^{242} appears to a small extent as the metal at mass 242 and much more intensely as $Cm^{242}O^+$ at mass 258. The ghost line one-third of a mass unit to the right of mass 258 is a characteristic of the machine and appears often on intense spectra. The isotopes Cm^{243} and Cm^{244} because of their small abundances are detected only at the more intense oxide masses 259 and 260.

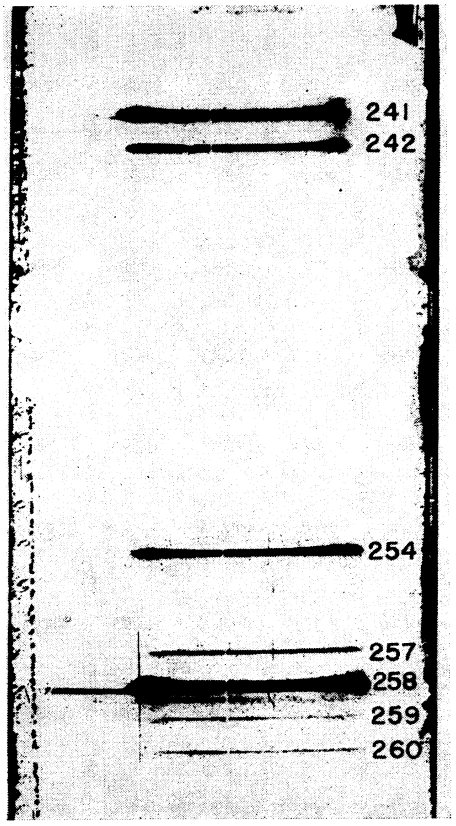

FIG. 1. Isotopic composition of the curium fraction from a long neutron irradiation of Am^{241}.

A photometer tracing of the plate gave the semiquantitative information that Cm^{243} and Cm^{244} are of about equal abundance in this sample and that each is about 1 percent as abundant as Cm^{242}.

The Cm^{243} was produced by the following sequence of nuclear reactions:

$$\begin{array}{c} Cm^{242}(n,\gamma)Cm^{243} \\ \uparrow \beta^-(16\text{ hr.}) \\ Am^{241}(n,\gamma)Am^{242m}. \end{array}$$

The Cm^{244} was undoubtedly produced both by neutron capture in the Cm^{243} formed as above and also by the following path:[1]

$$\begin{array}{c} Cm^{244} \\ \uparrow \beta^-(\sim 25\text{ min.}) \\ Am^{241}(n,\gamma)Am^{242}(n,\gamma)Am^{243}(n,\gamma)Am^{244}. \end{array}$$

Alpha-particles ascribed to Cm^{243} have been seen previously,[2,3] but the mass spectrographic identification of Cm^{244} represents the first definite evidence for this isotope.

From the energy balances involved one expects Cm^{243} to be slightly unstable with respect to orbital electron capture,[1] or possibly beta-stable. The alpha-decay systematics[4] predict that Cm^{244} is beta-stable with an alpha-decay half-life of years.

We would like to express our appreciation to Dr. S. G. Thompson for his very valuable assistance in carrying out this work.

* This work was performed under the auspices of the AEC.
[1] Street, Ghiorso, and Seaborg, Phys. Rev. **79**, 530 (1950).
[2] Street, Thompson, and Ghiorso (unpublished work).
[3] Rasmussen, Reynolds, Thompson, and Ghiorso, Phys. Rev. **80**, 475 (1950).
[4] Perlman, Ghiorso, and Seaborg, Phys. Rev. **77**, 26 (1950).

P–N Junctions Prepared by Impurity Diffusion

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September 8, 1950

WHEN $P-N$ barriers in a semiconductor are formed by the solidification of a melt, the concentrations of the different impurities which are present vary nearly linearly with distance from the barrier. The rectification properties of such barriers depend upon the donor and acceptor impurity gradients in such a manner that as the net concentration gradient is increased, the forward characteristic improves while the inverse breakdown voltage decreases.

By using a distinctly non-linear impurity distribution as indicated by Fig. 1, it is possible to construct rectifiers which combine the good forward characteristic of a large impurity gradient with the high inverse breakdown voltage of a barrier having a small impurity gradient. In the blocking direction, the potential drop is largely confined to a thin "barrier layer" within which the impurity concentration varies slowly. In the forward direction, holes and electrons are drawn in opposite directions across the rectifier from the regions of high impurity concentration where a copious supply of carriers is available. If the layers of high impurity concentration are not too greatly separated, space charge potentials due to recombination of holes and electrons can be made small and good forward characteristics are obtained.

The non-linear impurity distribution which is required may be obtained by thermal diffusion of donor and acceptor impurities into opposite sides of a wafer of semiconductor. Germanium diodes have been prepared in this manner which will withstand inverse potentials of the order of 100 volts and which will pass 500 amp./cm² at one volt in the forward direction. The charac-

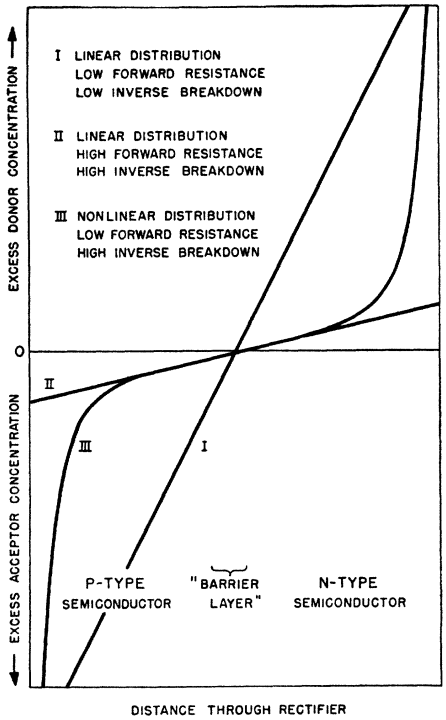

FIG. 1. Impurity distributions in semiconductor rectifiers.

teristics of these rectifiers are similar to those of selenium or copper oxide units except that the current densities are approximately 1000 times greater in the germanium units. Satisfactory rectifiers may be made from *N*- or *P*-type germanium having a resistivity of 5 ohm-cm or more.

When a rectifier is prepared by the diffusion of donor and acceptor impurities into the opposite sides of a wafer of extrinsic semiconductor, the barrier is located near one surface where the concentrations of donors and acceptors are equal. Accurate location of the barrier by means of a potential probe is possible and affords a sensitive method for the measurement of the diffusion of donor and acceptor impurities into semiconductors.

The Beta-Disintegration of Th^{233}

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September 8, 1950

THE 23.3-minute activity of Th^{233} has been studied in a magnetic lens spectrometer.[1] Sources were prepared by irradiating ThO_2 with neutrons in the thermal column of a nuclear reactor. The above decay rate was obtained by direct measurement for over eight half-lives and was also checked in the spectrometer. Sources were about 0.5 inch in diameter. The spectrometer was adjusted at a resolution of six percent during the investigation. Detection was by means of a 3.6-mg/cm² mica end-window counter.

The momentum distribution of the beta-particles is shown in Fig. 1 and the corresponding Fermi plot is shown in Fig. 2. There is clearly only one group of beta-rays. The extrapolated end point is 1.23±0.01 Mev. At high energies the Fermi plot is a straight line as might be expected, since the comparative half-life is only $ft \sim 10^6$. From the nuclear shell model one might expect this transition to involve a change of parity. The transition, therefore, appears to be of the once-forbidden type with a spin change of 0 or 1.

The downward deviation of the Fermi plot at low energy cannot be ascribed to source thickness or to counter window cut-off and is not fully understood. The data represented by circles were obtained using a source with 16 mg/cm² surface density mounted on 0.0002-inch aluminum backing. In order to examine the possibility that the apparent deficiency of low energy particles was due to source thickness, another source, with surface density of 0.6 mg/cm² mounted on a thin Zapon film, was studied in the spectrometer. These data are represented by triangles in Figs. 1 and 2. It is apparent that the use of a much thinner source

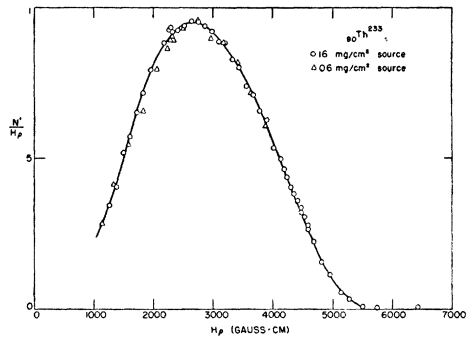

FIG. 1. Beta-spectrum of Th^{233}.

merely served to accentuate the downward deviation at low energy. This fall-off could possibly be due to a low energy defocusing effect in the spectrometer, although no other beta-ray spectrum analyzed with this instrument has exhibited any such deviation until below 200 kev. For example, the RaE spectrum, which has about the same end point and is located in the same part of the periodic table, was found to yield its characteristic shape, with no evidence of a deficiency of low energy electrons as reported above.

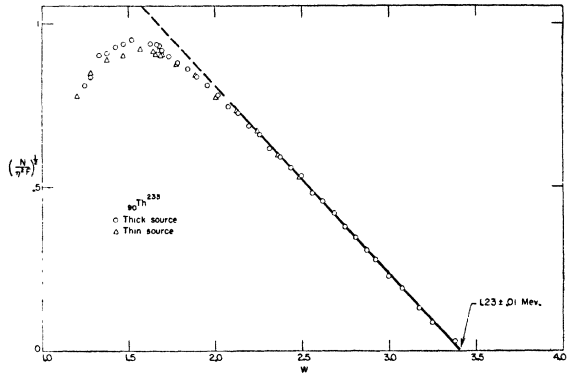

FIG. 2. Fermi plot of the data. The values for *F* were determined from the curves prepared by Moszkowski.

A search for gamma-rays was made by placing irradiated ThO_2 powder in a cylindrical copper capsule fitted with a uranium radiator. A very weak secondary electron distribution was observed which was interpreted as resulting from bremsstrahlung.[2] There was no evidence of photo-electron peaks. It is concluded that the beta-transition is directly to the ground state of Pa^{233}, as suggested by previous absorption measurements.[2]

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† This document is based on work performed under government contract for the Los Alamos Scientific Laboratory of the University of California.
[1] L. M. Langer, Phys. Rev. **77**, 50 (1950).
[2] Seaborg, Gofman, and Stoughton, Plutonium Project Report CN-126 (June, 1942), unpublished.