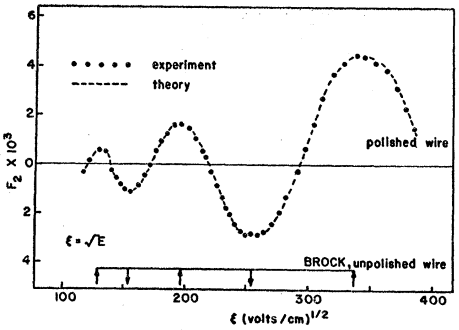

FIG. 1. Periodic deviations in the Schottky effect for a polished molybdenum filament, at 1600°K.

which accurate amplitude determinations could be made, an example of which is given in Fig. 1. In this figure the points are experimental, the dotted curve theoretical,[2] while the arrows along the axis of abscissas mark experimental extrema obtained for unpolished molybdenum filaments.[3] The amplitude maximum taken at $\xi=200$ from deviation curves for various temperatures is plotted against $1/T$ in Fig. 2. While some uncertainty is involved

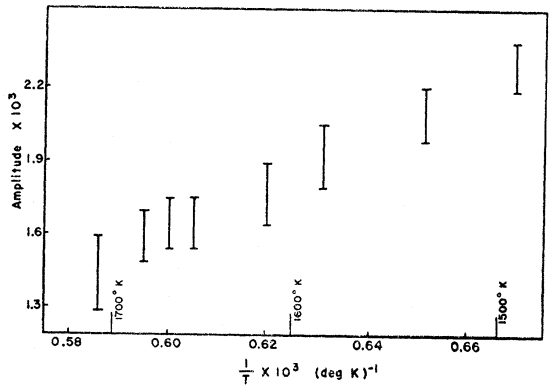

FIG. 2. Periodic deviation amplitude maximum at $\xi=200$, plotted against $1/T$. The range in amplitude indicates uncertainty in locating extrema on the deviation plot. (See Fig. 1.)

in locating the exact maximum of deviations, as indicated by the range at a given temperature, the tendency to increase with $1/T$ seems definitely apparent.

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Radioactive Isotope Separation by Nuclear Recoil*

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NUCLEAR reactions such as (γ,n), (d,p), and $(\alpha,2p)$ lead to product nuclides with the same atomic number as the initial nuclides. Unless the Szilard-Chalmers process[1] is practicable, it is usually difficult to achieve high specific activity for the product isotope. With light nuclei, however, the recoil momentum of the product nucleus can afford sufficient range to allow physical separation, as is clearly visible in nuclear emulsions.[2] When the ranges of the product nuclei are of the order of a micron, i.e., the size of colloidal particles, one may expect that in a fine powder mixture or in a colloidal suspension one phase or element can act as donor and the other as catcher. If the grain size of the donor is comparable to or smaller than the range of the recoiling product nucleus, the probability of stopping the radioactive nucleus within the "catcher phase" becomes high. Therefore, radioactive atoms will be transferred to the catcher phase from the donor phase.

To verify this experimentally, a preliminary experiment has been done using the $C^{12}(\gamma,n)C^{11}$ reaction in colloidal graphite solution. "Aquadag" solution of about 0.5-percent carbon by weight was bombarded by x-rays from the 70-Mev bremsstrahlung beam from the Iowa State College synchrotron, together with a control sample of powdered carbon. The colloid was precipitated and identical counting samples were prepared from the two target materials. It was found that the carbon bombarded as a colloid lost as much as 80 percent of its activity into the water phase. This result is understandable, since the carbon particles in "Aquadag" consist of small slabs with an approximate diameter of $\frac{1}{10}$ micron and much smaller thickness. The energies of recoiling C^{11} nuclei are expected to be of the order of a fraction of a Mev, corresponding to ranges of a fraction of a micron in carbon.

This method of separating isotopes may have importance in the production of Mg^{28} by $Mg^{26}(\alpha,2p)$.[3] For Mg^{28} production, a compressed powder of mixed Mg and some catcher metal such as tungsten might be used for good heat dissipation and ease of chemical separation. In the case of alpha-particle bombardment, particle sizes need not be less than one micron because of the high recoil momentum available.

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† On leave from the University of Tokyo, Tokyo, Japan.
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Mass Assignments by Isotope Separation*

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A TIME-OF-FLIGHT isotope separator constructed in this laboratory[1] has been used to assign mass numbers to several radioactive isotopes produced in cyclotron bombardments. Atoms of the mass numbers in question have been separated and the corresponding activity observed with a Geiger counter or other counting equipment.

The essential features of the instrument are high transmission (about 20 percent) at a resolution such that the separation factor between adjacent isotopes in the mass range 100–250 is about 100 or larger. In addition, the instrument is calibrated absolutely so that any desired mass number can be selected without the necessity of observing ion currents due either to the isotope being separated or to added stable isotopes.

Several isotopes of cesium (formed by α,xn reactions on iodine) have been separated in the course of work on their decay properties. Chemically separated carrier-free cesium sulfate fractions were ionized from a surface ionization source for this work. The previous assignments[2] of Cs^{127} and Cs^{129} were verified, with sufficient activity separated to establish the half-life of Cs^{127} as 6.1 ± 0.2 hours instead of the previously reported 5.5 hours. In addition, Cs^{130} has been separated and its half-life observed to be 30 minutes, in agreement with the previous result.[2]

A new isotope of cesium found by Mathur and Hyde of this laboratory, has been assigned to mass 125 and its half-life observed (from separated samples) to be 45 ± 1 minutes.

In connection with an investigation of the decay scheme of Cs^{136} by Olsen and O'Kelley[3] a large quantity of this isotope was separated for use in a beta spectrometer study of its decay. On the basis of the decay of part of the separated sample over nine half-

lives, the half-life has been determined by Olsen and O'Kelley as 12.9 days.

The neutron deficient thallium isotopes formed by bombardment of thick gold targets with 40-Mev helium ions have been separated and assigned directly. The activities at mass 199 and 200 have half-lives of 7.4±0.2 hours and 27±1 hours, respectively, and show gamma spectra in excellent agreement with the conversion electron work of Israel and Wilkinson.[4] The activity associated with mass 198 showed two distinct periods of 1.75 and 5.3 hours. These have been assigned to Tl^{198m} and Tl^{198}, respectively, by observation of the isomeric transition in the shorter isomer.[5] The ground state was independently discovered by Bergstrom, Hill, and de Pasquali at the University of Illinois.

Tl^{204}, produced by neutron capture in natural thallium, has recently been separated to test if an isomer of Tl^{206} is the cause of the various reports[7-9] of the half-life of Tl^{204}. Direct observation of the ion current due to Tl^{204} has also been made in a conventional magnetic mass spectrometer. No long-lived Tl^{206} could be detected by either method.

Considerable work with the heavy rare earth elements has been done with Nervik and Seaborg and will be reported separately. However, the following previously known isotopes have been assigned in the course of this work (half-lives are by direct observation of the decay of separated samples):

Yb^{166} 58±1 hours,
Yb^{169} 32 days,
Tm^{166} 7.7 hours,
Tm^{167} 9.6 days.

In addition, the following new isotopes formed in the spallation of tantalum with 350-Mev protons have been assigned:[10]

Tm^{165} 29 hours,
Er^{160} 30 hours,
Er^{161} 3.5 hours.

We would like to thank Mr. H. B. Mathur, Mr. W. E. Nervik, Dr. E. K. Hyde, and Professor G. T. Seaborg for their cooperation in many of these experiments.

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Decay Properties of Am^{243} and Possible Rotational Bands in the Alpha Spectra of Odd-Even Nuclei

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THE principal aim of this note is to show the close similarity in the alpha spectra of Am^{243} and Am^{241} insofar as comparison is possible and to suggest an interpretation for some of the observed levels. In earlier publications[1,2] the similarities in the spectra of even-even alpha emitters were demonstrated, and it now appears that alpha emitters with odd nucleons have points of similarity with each other but have a distinctly different pattern than the even-even nuclei.

The alpha-emitter Am^{243} was first prepared[3] through neutron capture by Am^{242} and its presence detected by observing the growth of Np^{239}. From mass spectrographic analysis of the americium and the amount of Np^{239} which grew, the half-life was estimated to be $\sim 10^4$ years.[3] The neutron irradiation of plutonium containing Pu^{242} creates Am^{243} through the intermediary Pu^{243} which is a short-lived β^- emitter,[4] and sufficient Am^{243} relative to Am^{241} could be produced in this way to measure the alpha-particle energy (5.27 Mev) with an ionization chamber.[5,6]

The sample of Am^{243} used for magnetic analysis in the present study was prepared by plutonium (Pu^{239}) irradiation. Only about 2 percent of the alpha activity was due to Am^{243} and the rest was Am^{241}.[7] Nevertheless, the more prominent features of the Am^{243} alpha spectrum could be measured. From the resolved alpha spectra and the isotopic abundance of Am^{243} in the sample, the half-life was calculated to be 7.6×10^3 years. The magnetic spectrograph has been described in earlier publications.[8,9]

Three alpha groups attributable to Am^{243} were observed with energies and abundances as indicated in Fig. 1. The alpha groups of Am^{241} were used as energy standards.[9] In comparing the spectrum with that of Am^{241}, it will be noted that the main group of Am^{241} (84 percent abundance) populates a state 60 kev above the ground state,[10] and the main group of Am^{243} (84 percent abundance) leads to an excited state of 75 kev. The alpha-gamma coincidence measurements which established this decay sequence will be mentioned presently. Each alpha emitter has a transition in about 14 percent abundance of some 40-kev lower energy than the main alpha transition and each has a low-intensity group of about 55-kev still lower energy. It is seen that the parallelism is close for those transitions which can be compared.

The ground-state alpha transition for Am^{243} was not observed, but the limit of detection was 2.5 percent and it will be noted that the corresponding transition for Am^{241} is found in only 0.3 percent abundance. Similarly, if there is a low-abundance transition (energy level shown as a broken line) corresponding to that populating the 33-kev state of Np^{237} from Am^{241} decay, it would not have been seen. Purer and more intense souces of Am^{243} will be required to see if this state exists.

A small amount of a sample was available which had about twice as much Am^{243} activity as Am^{241}, and this was used for a gamma-ray study. A scintillation spectrometer triggered by coincident alpha particles was employed in order to obtain the gamma-ray energies and abundances. A single prominent peak was obtained at 75 kev which showed a hump on the low-energy side presumably due to the 60-kev gamma ray of Am^{241}. Since the Am^{241} content was known, its contribution to the gamma-ray peak could be subtracted. The result was that the 75-kev gamma ray was found to accompany 80 percent of the total Am^{243} alpha particles. This means that the conversion coefficient cannot be greater than 0.25 and fixes this transition as $E1$ just as is the case for the 60-kev transition of Am^{241}.[11] (The conversion coefficients of 75-kev $M1$ and $E2$ transitions should be 10 or greater.[12])

If we consider those components of the Am^{243} spectrum which lead to the 75-kev state and to the next two higher states, we note a marked resemblance to the ground state and first two excited states of an even-even alpha emitter like Cm^{242}.[13] The similarity includes energy level spacings and the intensities of the alpha groups. In the case of an even-even nucleus this type of spectrum has been interpreted as a rotational band comprising the states 0+, 2+, and 4+.[13]

According to the theory of Bohr and Mottelson,[14] the rotational states of an odd-nucleon case could have the following energy and

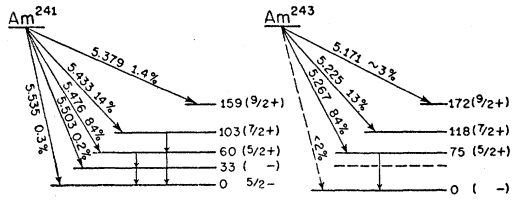

FIG. 1. Partial decay schemes for Am^{241} and Am^{243}.