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

FRANK ASARO AND I. PERLMAN
Radiation Laboratory and Department of Chemistry, University of California, Berkeley, California
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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

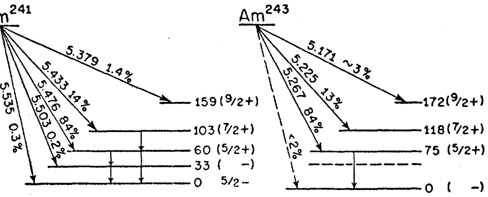

FIG. 1. Partial decay schemes for Am^{241} and Am^{243}.

spin sequence:

$$E_I=\frac{\hbar^2}{2\mathcal{I}}[I(I+1)-I_0(I_0+1)];\quad I=I_0,\quad I_0+1,\quad I_0+2,\cdots,$$

where I_0 is the spin of the lowest state in the band.

If one has three adjacent states belonging to a rotational band, it should be possible to calculate I_0 (and therefore I_0+1 and I_0+2) as well as the quantum of rotation, $\hbar^2/2\mathcal{I}$. On this basis the spins of the states reached by Am^{241} α_{60} and Am^{243} α_{75} were calculated to be 2.3 and 2.8, respectively. Since the spins must be half-integral, the closest value is 5/2. This same treatment of Am^{241} data was made by Rasmussen[15] who arrived at similar conclusions for the spin numbers of the excited states. It should be mentioned that the calculated spin number is sensitive to the accuracy of the energies of the states. If the measured energy difference between Am^{241} α_{60} and α_{103} were 44 kev instead of 43 kev, the value obtained for I_0 would have been 2.8 instead of 2.3.

From shell-model considerations, the ground states of Np^{237} and Np^{239} are assigned odd parity. Since the 60-kev and 75-kev transitions are $E1$, the levels belonging to the rotational band have even parity. The spin and parity assignments made on this basis are shown in Fig. 1. The spin number 5/2 for the ground state of Np^{237} is a measured value.[16]

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Cross Sections for *p-p* Scattering at 330 and 225 Mev*

O. Chamberlain, G. Pettengill, E. Segrè, and C. Wiegand
Radiation Laboratory and Department of Physics, University of California, Berkeley, California

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THE total cross sections for scattering of high-energy protons by protons have been directly measured at the full and at one reduced energy of the Berkeley synchrocyclotron. Attenuation of the external proton beam in liquid hydrogen was measured with standard counting techniques in order to check, by an independent method, the results obtained in previous differential scattering experiments.

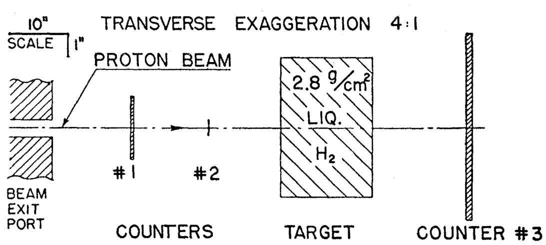

Fig. 1. Schematic diagram of the experimental geometry.

Figure 1 shows the experimental setup. The counting rate of counters 1–2–3 in coincidence was subtracted from the 1–2 coincidence rate and divided by the latter to obtain the attenuation occurring between counters 2 and 3. The difference in this quantity for the target filled with liquid hydrogen and for the empty target is attributed to scattering of the beam through an angle greater than the average half-angle subtended by the rear counter (No. 3).

The experiments were made with the full-energy beam (340 Mev) and at an energy of 240 Mev. Reduction of the beam energy was achieved by inserting $7\frac{1}{8}$ inches of beryllium in the path of the emerging beam before the existing analyzing magnet inside the shielding. Counting difficulties arising from the low duty cycle of the synchrocyclotron were minimized by holding the average external beam level below 10 protons per second. The use of scintillation counters ensured counting efficiencies of substantially 100 percent and also allowed a pulse-height investigation of beam homogeneity. The target is constructed of polystyrene foam.

Thus we have measured directly the attenuation f and may calculate:

$$\sigma_{\mathrm{obs}}=\frac{M(f_H-f_B)}{\rho t[1-\frac{1}{2}(f_H+f_B)]},$$

where the subscripts H and B refer to target filled and empty, respectively, M is the mass of the hydrogen atom, and ρt is the surface density of the liquid hydrogen in the target. The small values of f obtained (not exceeding 0.05) justify the degree of approximation involved in the equation. σ_{obs} is related to the differential scattering cross section through the expression

$$\sigma_{\mathrm{obs}}=\int_{\theta_{\min}}^{90°}\frac{d\sigma}{d\Omega}2\pi\sin\theta d\theta=2\pi\cos\theta_{\min}\left\langle\frac{d\sigma}{d\Omega}\right\rangle_{\mathrm{Av}},$$

where $\theta_{\min}$ is the average half-angle subtended by the rear counter in the center-of-mass system and was varied around 18° in this experiment. It should be noted that this angle is too large to include the Rutherford scattering at either energy, or the small contribution from the inelastic reaction $p+p\rightarrow\pi^++d$ at the full energy. The values obtained were

Mean energy (Mev)	$\langle d\sigma/d\Omega\rangle_{\mathrm{Av}}$ in units of 10^{-27} cm²/sterad
330	3.72 ± 0.15
225	3.56 ± 0.15

The errors shown include statistical and target-thickness uncertainties.

Since previous differential scattering work has shown, for the energies considered here, that $d\sigma/d\Omega$ is essentially constant over the range of angles included in σ_{obs}, $\langle d\sigma/d\Omega\rangle_{\mathrm{Av}}$ may be compared directly with the corresponding differential data. In this comparison our experimental results are consistent with those of a previous paper[1] and those of Marshall *et al.*,[2] but seem at variance with the results of Oxley and Schamberger[3] and Towler.[4]

Extension of this method to a lower energy is planned in the near future, after which a complete report will be submitted.

* This work was done under the auspices of the U. S. Atomic Energy Commission.

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Neutral-to-Charge Ratio in High-Energy Interactions*

M. F. Kaplon, W. D. Walker, and M. Koshiba
University of Rochester, Rochester, New York

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ONE of the problems of primary interest in the study of elementary particles is the determination of their production efficiency as a function of energy. At energies well removed from threshold, cosmic rays furnish the only source of high-energy