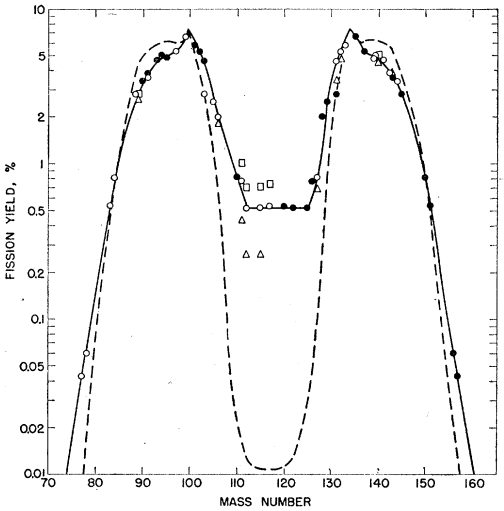

FIG. 1. Photofission yields of uranium at 22 Mev, 48 Mev, and 100 Mev. Dashed curve is that of thermal-neutron fission of U^{235}, solid curve for 48-Mev x-rays. △, 22 Mev; ○, 48 Mev; ●, 48 Mev reflected yields; □, 100 Mev. The yield of Mo^{99} at 22 Mev and 100 Mev is normalized to 6.6 percent.

127 it was noted that more concordant agreement was obtained with a mass sum[14] of 237. The curve is normalized to 200 percent total fission yield.

The peak-to-trough ratio, as determined from the yields at masses 97 and 115, was observed to be dependent upon the maximum energy of the x-ray beam, varying from 7 at 100-Mev maximum energy to 20 at 22-Mev maximum energy. These results, as well as those of other reported experiments, are summarized in Table I. The fact that the peak-to-trough ratio was

TABLE I. Peak-to-trough ratios at various x-ray energies.

Energy of x-rays, Mev	Nuclide irradiated	Peak-to-trough ratio	Reference
2.6, fission neutrons	U^{238}	100	Engelkemeir, Seiler, Steinberg, and Winsberg. See reference 10, Paper 218.
10	U^{238}	126	See reference 6.
16	U^{238}	121	See reference 6.
~20	U^{235}	20	See reference 4.
22	U^{238}	20	This paper.
48	U^{238}	10	This paper.
69	Th^{232}	10	D. M. Hiller and D. S. Martin, Jr., presented before the 122nd Natl. Meeting of the American Chemical Society, Sept. 14–18, 1952.
100	U^{238}	7	This paper.

observed to change from 48 to 100 Mev indicates that absorption of photons is occurring in this energy interval and that the average fission process is of a more symmetric type than that occurring at lower energies. The fission activation curve for uranium given by Baldwin and Klaiber[15]—their cross-section curve has a maximum at 16 Mev with a half-width of about 4 Mev, and approaches zero at about 33 Mev—must then have a high energy tail. If it is assumed that the trough yield at high energy is due to symmetric fission,[11] then the contribution to the total fission rate from photons of 48 to 100 Mev energy amounts to about 3 percent.

Further work on the (γ,f) reaction of uranium is planned at the 330-Mev University of Illinois Betatron. Work is also in progress on independent yields of some shielded nuclides and other selected fission products.

We wish to acknowledge the assistance of Mr. B. C. Cook and the Betatron Group, Mr. M. Fielding and the staff of the 37-inch cyclotron of the University of Chicago, and the personnel of the Argonne National Laboratory responsible for the thermal neutron irradiations. The 22-Mev irradiations at the University of Illinois Betatron were accomplished through the generous cooperation of Professor D. W. Kerst and Mr. T. J. Keegan.

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Assignment of Y^{92} and Y^{94}*

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A SHORT-LIVED isotope of yttrium assigned to Y^{94} has been reported as a fission product from uranium[1] and plutonium[2] and as the result of an (n,p) reaction on zirconium.[3] A recent investigation of the isotope indicates that the half-life is 16.5±1 minute,[4] but the mass assignment of this activity is still listed[5,6] as "probable but not certain." In addition, the assignment of the 3.5-hour yttrium activity to Y^{92} has recently been reclassified[5] as "probable but not certain."

We have checked the mass assignment of these activities by comparing relative bombardment yields of Y^{90}, Y^{92}, and Y^{94} prepared by the (d,α) reaction. Zirconium metal (high purity foil except for two percent hafnium content) was bombarded in the 7.8-Mev deuteron beam of the University of Michigan cyclotron and the yttrium produced was separated chemically. The foil was dissolved in dilute hydrofluoric acid, carriers of niobium and yttrium added, and the yttrium precipitated as the fluoride. This precipitate was metathesized to the hydroxide and then dissolved. The resulting solution was scavenged with zirconium phosphate and niobic acid precipitates to complete the separation. A final precipitate of yttrium fluoride was slurried onto copper plates for counting. The total separation required about 25 minutes. It gave a decontamination from zirconium and niobium of at least 10^4 and a yield of yttrium of about 50 percent.

Decay of the samples was followed for several weeks to determine the relative yields of the yttrium isotopes formed. The gross decay of the yttrium samples was resolved into a 65-hour, a 3.5-hour, and an 18-minute line. No 2.0-hour Y^{88m} was detected in the decay. A small amount of 105-day Y^{88} was undoubtedly formed in the bombardment, but its yield was so low as to be scarcely detectable above background. The energy of the bombardment was low enough that no products of a $(d,\alpha n)$ reaction were observed. The lutecium isotopes arising from a (d,α) reaction on the small amount of hafnium impurity present in the target material were not separated by the chemical procedure but were formed in such low abundance that their effect on the decay curve was negligible.

Absorption curves taken at different times on the above samples indicated that the 18-minute isotope emitted a beta-particle of energy greater than 5 Mev; the 3.5-hour isotope emitted a beta-particle of about 3.5-Mev energy and a gamma-ray of about 0.5 Mev; while the 65-hour activity emitted a beta-particle of 2.35 Mev. These energy data are consistent with the values reported in the literature.[5]

The experimental yields for these three isotopes normalized to

TABLE I. Yields of zirconium isotopes.

Zr mass	Rel. abundance (%)	Relative yields Theoret.	Run I	Run II
92	17.1	1.00	1.00	1.00
94	17.4	1.02	1.06	1.07
96	2.80	0.164	0.186	0.169

the 65-hour Y^{90} activity are presented in Table I, together with the theoretical yields expected from the abundance data.

It can be seen that the results of both bombardments agree very well with the theoretical yields. This agreement lends very strong support to the assignment of the 16.5-minute yttrium activity to Y^{94} and the 3.5-hour activity to Y^{92}. It also substantiates the assignments of the strontium, rubidium, and krypton isobars of mass 92 and 94 whose genetic relationship to the yttrium activities has already been shown. This method of mass assignment has presupposed equal yields for all the (d,α) reaction products from the even-even isotopes of zirconium and has presumed no isomeric states of Y^{90}, Y^{92} and Y^{94} to consume part of the (d,α) reaction yield. Both of these assumptions appear to be good in this case.

It should be pointed out, however, that this method of mass assignment by equal yields has been shown to be valid only for the (d,α) reaction products of even-even isotopes. Other work in progress at this laboratory appears to show considerable difference in (d,α) reaction yields for mixed even-even and even-odd parents.

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The Gamma-Radiation from Am^{241}

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IN a recent letter[1] we have reported measurements made with a proportional counter on the gamma- and L radiation following the alpha-decay of Am^{241}. Browne,[2] using a crystal spectrometer and thick sources, has also made measurements on this nuclide and has reported gamma-rays of energies 38.0 kev, 33.4 kev, 22.2 kev, and 18.8 kev in addition to those which we found. The first two of these were stated to have intensities of 6 percent and of 28 percent, respectively, relative to that of the 59.7-kev gamma-ray; it would not have been possible for us to resolve the last two from the Np^{237} L radiation with our instruments. The location of these lines together with a further line at 14.4 kev in a decay scheme is discussed briefly by Asaro, Reynolds, and Perlman[3] who state that it is necessary to assume the presence of levels in Np^{237} other than those directly excited by the observed alpha-particle groups.

In view of this apparent anomaly, we have re-examined the spectrum more closely in the energy region 26–41 kev using proportional counters filled with krypton and xenon. A typical spectrum obtained, using a carrier free source of Am^{241} and a krypton filled proportional counter, is shown in Fig. 1. An upper limit of 0.1 percent[4] per 59.7-kev γ-ray can be set to the intensity of gamma-rays at 33.4 and 38.0 kev from the combined measurements.

In Fig. 2 is shown a spectrum, obtained from an Am^{241} source containing lanthanum which is commonly used as a carrier for Am, in which strong lines are present at ~33.1 and 38.0 kev, having a relative intensity (~5:1) similar to that observed by Browne. These are clearly the $K\alpha$ and $K\beta$ radiations of lanthanum excited by the 59.7-kev gamma-ray. The mean energies of the lanthanum $K\alpha$ and $K\beta$ lines are 33.4 and 37.9 kev, to be compared with the values of 33.4 and 38.0 kev reported by Browne for the "γ-rays". We therefore suggest that these lines are not of nuclear origin.

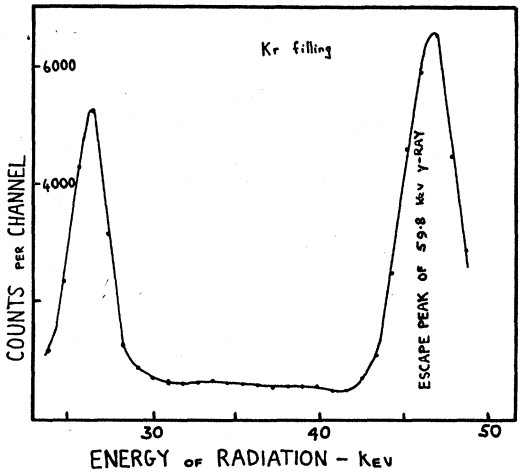

FIG. 1. Spectrum obtained with thin carrier free source of Am^{241}.

Similarly, the energies of the weaker gamma-rays mentioned above, namely, 14.4, 18.8, and 22.2 kev, are to be compared with those of the $L\alpha_1$, $L\beta_1$, and $L\gamma_1$ radiation of Am, namely, 14.6, 18.8, and 22.0 kev. Furthermore, the relative intensities are consistent with the hypothesis that these lines are due to fluorescent excitation of the Am source by the 59.7- and 26.3-kev radiations which are known[1] to accompany the decay process.

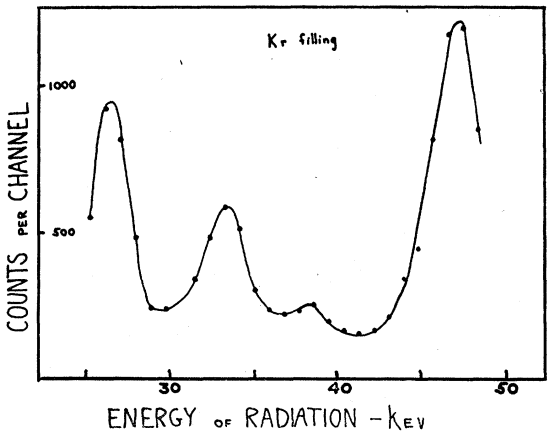

FIG. 2. Spectrum obtained with Am^{241} source containing La carrier, showing presence of lines at 33.1 and 38.0 kev.

It therefore appears to be unnecessary to assume the presence of low-lying levels in Np^{237} other than those excited directly by the observed alpha-particle groups.[3]

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