TABLE I. Experimental data for neutron-proton scattering at 90 Mev. θ is the scattering angle in the center-of-mass system. Column I gives the ratio of the differential cross section in the center-of-mass system at the angle θ to that at 36°. Column II gives the absolute differential cross section obtained by normalizing to the results of Hadley *et al.* (see reference 1). The errors listed are the standard deviations of the counting statistics.

θ	I Relative cross section	II Absolute cross section (10^{-27} cm^2/steradian)
5.1	1.70 ± 0.14	12.9 ± 1.2
10.3	1.58 ± 0.06	12.0 ± 0.7
20.8	1.36 ± 0.05	10.3 ± 0.6
36.0	1.00	7.6 ± 0.4

processes, counter 1 was connected in anticoincidence. Only events detected in counters 2 and 3 but not 1 were counted.

The thickness of absorber 2 determined the minimum energy which a scattered neutron could have and still be counted. In the present work the minimum energy was adjusted at each scattering angle to be [(60 Mev) $\cos^2\Theta$]. Therefore, a neutron in the beam must have had at least 60 Mev in order to have been counted after scattering, since otherwise the proton yielded at the converter would have had insufficient range to reach counter 3. The shaped portion of absorber number 2 was thickest in the center and was shaped so that to good approximation the minimum neutron energy to count would be independent of the angle with which the recoil proton emerged from the converter. To determine the shape of the absorber we assumed that most of the recoil protons were from n-p scattering processes in the converter. In order to ascertain whether the relative differential cross sections were particularly sensitive to the value of the minimum energy for detection of the scattered neutrons, a measurement was made with this minimum energy increased to 66 Mev. The results were in agreement with those obtained for the 60-Mev minimum within the uncertainty of the counting statistics.

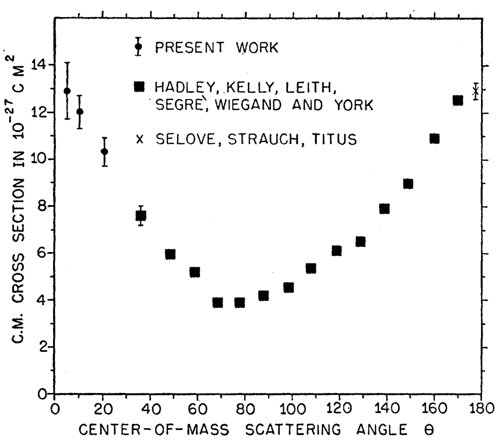

FIG. 2. Differential neutron-proton cross section in the center-of-mass system in 10^{-27} cm^2/steradian.

The results are tabulated in Table I. Figure 2 shows the data in their relation to prior work, indicating a marked similarity of the differential cross section in the region of 0° to that in the region of 180°.

Thanks are due Dr. Martin O. Stern for initial studies of background and design of the neutron collimator.

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[1] Hadley, Kelly, Leith, Segrè, Wiegand, and York, Phys. Rev. **75**, 351 (1949).
[2] Brueckner, Hartsough, Hayward, and Powell, Phys. Rev. **75**, 555 (1949).
[3] R. H. Fox, U. S. Atomic Energy Commission Report UCRL-867, 1950 (unpublished).
[4] R. Wallace, Phys. Rev. **81**, 493 (1951).
[5] Selove, Strauch, and Titus, Phys. Rev. **92**, 724 (1953).
[6] C. Y. Chih and W. M. Powell (private communication).

Additional Properties of Isotopes of Elements 99 and 100

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A SHORT-LIVED alpha activity was previously reported to elute at the element-100 position.[1] This activity was observed, a few hours after column separation, to be in equilibrium[1] with an element-99 parent which decayed with a longer (~2-day) half-life. Preliminary data obtained from irradiations in the Argonne pile indicated that an MTR irradiation of 10^4 alpha counts/minute of the 6.6-Mev element-99 isotope would produce several hundred 7.2-Mev alpha counts/minute of element 100.

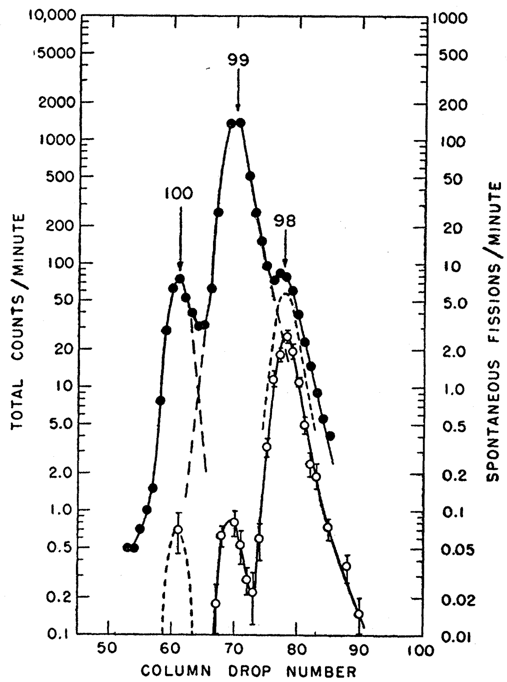

FIG. 1. The solid points represent the total counts/minute (alphas plus spontaneous fissions) from each drop at the time of removal from the cation column. The dashed curves outline the individual element separations as determined by alpha-pulse analysis and spontaneous fission measurements. The open circles represent the spontaneous fission activity as a function of drop number. The value at drop 61 is a result of a spontaneous fission activity measurement immediately after column elution. The other spontaneous fission measurements were made more than 12 hours after column elution, and therefore isotope 100^{254} was in approximate equilibrium with its element-99 parent causing the spontaneous fissions on the element-99 drops.

This note describes the results obtained from a four-day irradiation of an element-99 fraction with californium impurity in the Materials Testing Reactor (MTR) at Arco, Idaho to produce the following reaction:[2]

$$99^{253}(n,\gamma)99^{254} \xrightarrow{\beta^-} 100^{254}.$$

The separation of elements 98, 99, and 100 has been discussed previously and the degree of separation in this experiment is shown in Fig. 1. The peak of the 7.2-Mev alpha activity of element 100 eluted from the cation resin column on drop 61, while the peak of elements 99 and 98 eluted on drops 69–70 and 78, respectively.

The 7.2-Mev alpha-emitting isotope of element 100 decayed with a 3.3 ± 0.2 hour half-life (Fig. 2) measured both by total and by spontaneous fission activity. The ratio of 7.2-Mev alpha

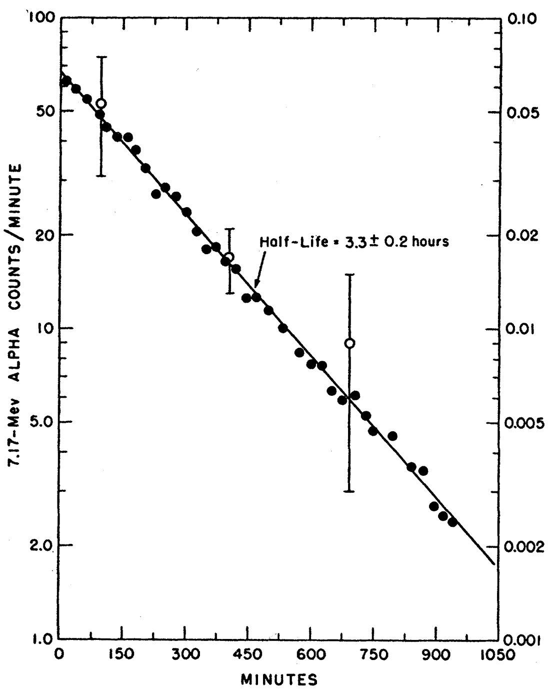

FIG. 2. Decay of the element-100 fraction. The solid points represent the 7.17-Mev alpha counts/minute of drop 60 as a function of the time in minutes. The open circles represent the spontaneous fission activity of drop 61 as a function of time.

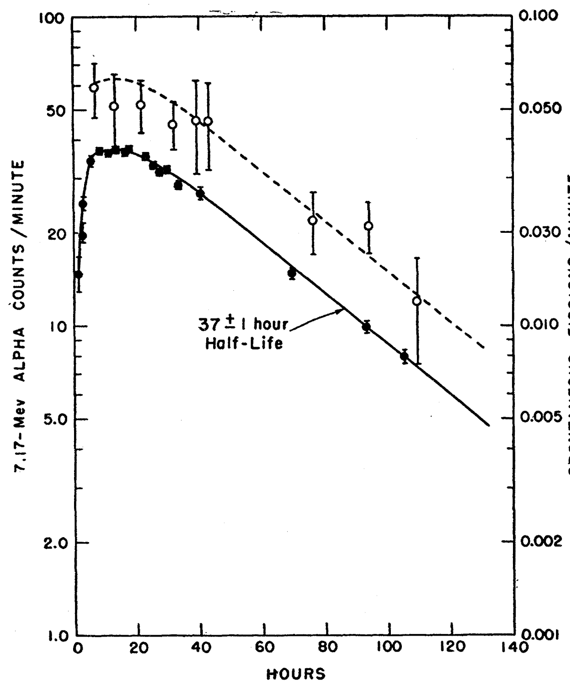

FIG. 3. Growth and decay of element-100 isotope in an initially separated element-99 fraction. The solid circles represent the 7.17-Mev alpha activity on drop 71 as a function of time. The open circles represent the spontaneous fission activity on drop 68 as a function of time. The dashed line is a parallel displacement of the solid line.

disintegrations to spontaneous fission disintegrations on drop 61 was 2000±700.

The 7.2-Mev alpha activity was observed to grow into the purified element 99 fraction (drops 69, 70, 71) by alpha-pulse analysis, and eventually decayed from the 99 fraction with a 37-hour half-life (see Fig. 3). The spontaneous fission activity on drop 68 followed a similar growth-decay curve (Fig. 3). Figure 1 shows the spontaneous fission peak in the element-99 fraction after the element-100 (7.2-Mev alpha) had grown into equilibrium. These experiments confirm the genetic relation of the 7.2-Mev alpha-emitting isotope of element 100 to its element-99 parent. In addition, a measurable spontaneous fission activity is shown to be associated with the element-100 isotope emitting the 7.2-Mev alpha particles.

The ratio of 7.2-Mev alpha disintegrations to spontaneous fission disintegrations was measured more accurately with samples containing element 100 in equilibrium with the element-99 parent. The ratio is 1600±300, in good agreement with the less accurate value from drop 61. The calculated spontaneous fission half-life of the 3.3±0.2 hour element-100 isotope is 220±40 days. This half-life is in agreement with the prediction for an even-*A* isotope of element 100 with mass 254, and is corroborative evidence for the even-*A* assignment.[3]

An equilibrium sample (the specific 7.2-Mev alpha activity four-hundred-fold greater than that in the previous measurement described in reference 1) of 100^{254} supported by its parent 99^{254} was employed for additional alpha-spectrum studies. The energy of the prominent alpha group was measured to be 7.17±0.01 Mev, in close agreement with the initial measurement of 7.20 Mev.[1] More discussion on the 7.03-Mev alpha emitter will be included in a later manuscript. The pile neutron capture cross section of 99^{253} is 240±100 barns, assuming no electron-capture branching in the decay of 99^{254}.

The nuclear properties of isotopes of elements 99 and 100 are summarized in Table I.

TABLE I. Nuclear properties of some isotopes of elements 99 and 100.

Isotope	Radiation	Half-life	Alpha energy (Mev)	Spontaneous fission half-life
99^{253}	α	19.3 ±0.3 days	6.61 ±0.01	$>10^5$ yr
99^{254}	β^-	37 ±1 hr		>10 yr
100^{254}	α	3.3 ±0.2 hr	7.17 ±0.01	220±40 days

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[1] Studier, Fields, Diamond, Mech, Friedman, Sellers, Pyle, Stevens, Magnusson, and Huizenga, Phys. Rev. **93**, 1428 (1954).
[2] The tentative mass assignments are based on mass yields and heavy-element systematics.
[3] J. R. Huizenga, Phys. Rev. **94**, 158 (1954).