

Little can be said about the detailed shape of the  $\epsilon$  vs  $\theta$  curve because of the large statistical errors.

\* Research supported by a joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

<sup>1</sup> Oxley, Cartwright, and Rouvina, *Phys. Rev.* **93**, 806 (1954).

<sup>2</sup> Chamberlain, Segrè, Tripp, Wiegand, and Ypsilantis, *Phys. Rev.* **93**, 1430 (1954).

<sup>3</sup> Marshall, Marshall, and de Carvalho, *Phys. Rev.* **93**, 1431 (1954).

<sup>4</sup> J. M. Dickson and D. C. Salter, *Nature* **173**, 946 (1954).

<sup>5</sup> de Carvalho, Marshall, and Marshall, *Phys. Rev.* **96**, 1081 (1954).

<sup>6</sup> Chamberlain, Segrè, Tripp, Wiegand, and Ypsilantis, *Phys. Rev.* **95**, 1105 (1954).

## New Elements Einsteinium and Fermium, Atomic Numbers 99 and 100

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THIS communication is a description of the results of experiments performed in December, 1952 and the following months at the University of California Radiation Laboratory (UCRL), Argonne National Laboratory (ANL), and Los Alamos Scientific Laboratory (LASL), which represent the discovery of the elements with the atomic numbers 99 and 100.

The source of the material which was used for the first chemical identification of these elements was the Los Alamos Scientific Laboratory which provided uranium which had been subjected to a very high instantaneous neutron flux in the "Mike" thermonuclear explosion (November, 1952). Initial investigations at ANL showed the presence in this material of the new isotope  $\text{Pu}^{244}$ ,<sup>1</sup> and investigations at ANL and LASL showed the presence of  $\text{Pu}^{246}$  and  $\text{Am}^{246}$ ,<sup>2</sup> pointing to the presence of neutron excess isotopes in greater abundance than expected.

This led the UCRL group to look for isotopes of transcalifornium elements in material from the same source. Samples were subjected to chemical procedures to separate the actinide from the lanthanide fraction,<sup>3</sup> tracer  $\text{Cf}^{246}$  (36-hour, 6.75-Mev alpha particle<sup>4</sup>) was added and a separation of the tripositive actinides was effected using the cation-exchange resin Dowex-50 and elution at 87°C with ammonium citrate solution.<sup>5</sup> These experiments showed the elution in a transcalifornium position of a 6.6-Mev alpha activity and hence proved conclusively that a new (transcalifornium) element had been found. Before the atomic number

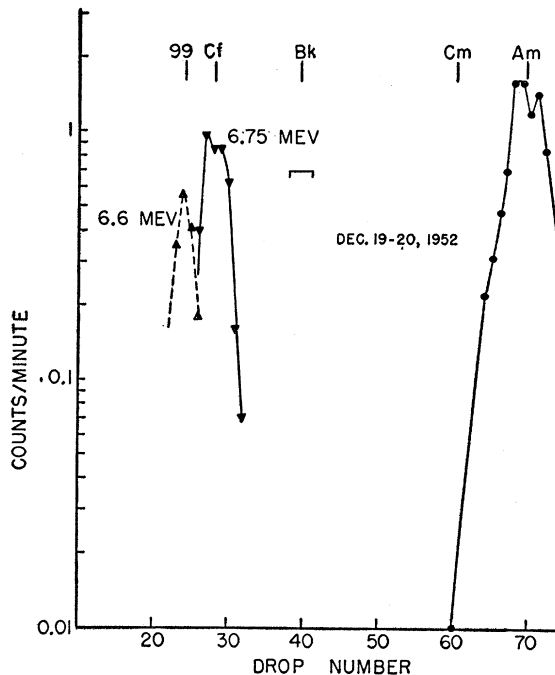


FIG. 1. Elution of element 99 relative to californium (citrate eluant).

identification for the newly discovered element was completed (i.e., the correct choice between atomic numbers 99 and 100 had been made) a tentative assignment to " $100^{254}$ " was made and this information was communicated to the ANL and LASL Laboratories. Immediately following this, further ion-exchange elution separations were carried out at both UCRL and ANL resulting in essentially simultaneous identification of the 6.6-Mev alpha activity as belonging to the element with atomic number 99 (i.e., elution in the eka-holmium position). The results of these definitive elution experiments are shown in Fig. 1.

Further measurements on material from the same source by the LASL group led to the observation of a 7.1-Mev alpha activity (at an intensity of about 4 percent of that of the 6.6-Mev alpha activity) without chemical identification beyond proving that it was due to a transplutonium element. This 7.1-Mev alpha activity was first shown by the UCRL group in ion-exchange elution experiments of the type described above to be an isotope of element 100 (i.e., elution in the eka-erbium position just ahead of the 6.6-Mev element 99 alpha activity) and was shown to have a half-life of about a day sustained by a longer-lived element 99 parent. This establishment of the isotope responsible for the 7.1-Mev alpha activity as having the atomic number 100 was confirmed in a similar experiment by the ANL group somewhat later. The elution data for the experiments that established this atomic number are shown in Fig. 2. The californium, berkelium,

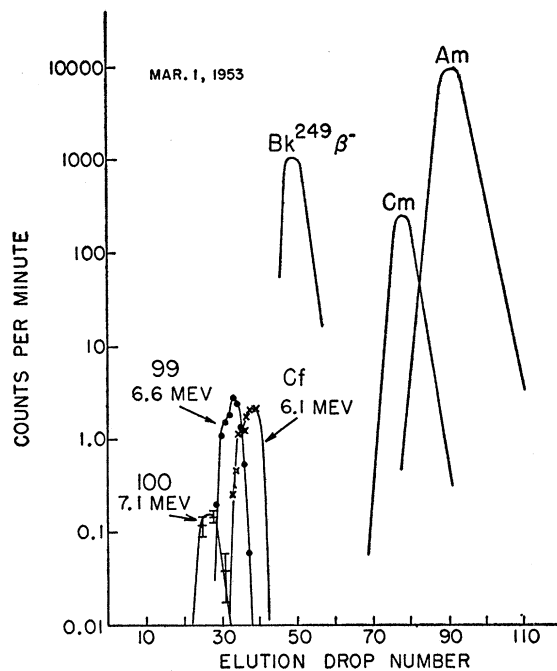


FIG. 2. Elution of element 100 relative to other actinide elements (citrate eluant).

and curium radioactivities will be discussed in a forthcoming publication.

Isotopic assignments which were made as the result of this early work were largely confirmed by the later work on the intense neutron irradiation<sup>6-9</sup> of  $\text{Pu}^{239}$ . Thus it can be said that the mass number for the 6.6-Mev 99 alpha activity is 253, corresponding to the decay sequence  $\text{Cf}^{253} \xrightarrow{\beta^-} 99^{253}$  ( $\sim 20$ -day, 6.6-Mev alpha particle), the  $\text{Cf}^{253}$  originating from the beta decay of  $\text{U}^{253}$  and daughters. Also, the mass number for the 7.1-Mev 100 alpha activity is 255 corresponding to the decay sequence  $99^{255} \xrightarrow{\beta^-} 100^{255}$  ( $\sim 16$ -hour, 7.1-Mev alpha particle), the  $99^{255}$  originating from the beta decay of  $\text{U}^{255}$  and daughters.

We suggest for the element with the atomic number 99 the name einsteinium (symbol E) after Albert Einstein, and for the element with atomic number 100 the name fermium (symbol Fm), after Enrico Fermi.

The primary acknowledgment is to the personnel of LASL for the design and construction of the thermo-nuclear (Mike) weapon, which gave rise to the extreme neutron flux required to produce the very heavy nuclides. We wish to thank H. F. Plank for his very able direction of the sampling operation. In addition the ANL group wishes to acknowledge helpful discussions with A. Turkevich and its indebtedness to D. F. Peppard and his group (George Mason, John Maier, and Richard Wallace), who isolated a heavy element fraction. The LASL group wishes to acknowledge its

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<sup>1</sup> Hess, Pyle, Fried, and Inghram (to be published).

<sup>2</sup> Asprey, Browne, Engelkemeir, Fields, Fried, Pyle, Smith, Spence, and Stevens (to be published).

<sup>3</sup> K. Street, Jr., and G. T. Seaborg, *J. Am. Chem. Soc.* **72**, 2760 (1950).

<sup>4</sup> Ghiorso, Thompson, Street, and Seaborg, *Phys. Rev.* **81**, 154 (1951).

<sup>5</sup> See, e.g., Thompson, Street, Ghiorso, and Seaborg, *Phys. Rev.* **80**, 790 (1950).

<sup>6</sup> Thompson, Ghiorso, Harvey, and Choppin, *Phys. Rev.* **93**, 908 (1954).

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## Multiple Meson Production in Emulsions Exposed to the Bevatron Beam\*†

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MEASUREMENTS have been made on the shower-particle production in nuclear stars formed in 600-micron Ilford G.5 stripped emulsions. Production

TABLE I. Observed and calculated shower-particle multiplicity percentages—Fermi model.

Energy in Bev	$n_s$	Extension of Fermi's calculations*	Experimental observations
3.2	0	20	42
	1	47	28
	2	29	25
	3	4	4
	4	...	1
	Av $\bar{n}_s$	1.17	0.94±0.09
4.8	0	16	25
	1	41.5	38
	2	35	20
	3	7.5	17
	4	...	0
	Av $\bar{n}_s$	1.34	1.3±0.11
5.7	0	14	17
	1	38	31
	2	38	30
	3	10	18
	4	...	3
	5	...	1
Av $\bar{n}_s$	1.44	1.62±0.11	

\* In the computation of the percentages for each value of  $n_s$  the tabulated number represents the shower tracks that would actually be observed, not the number of pions created. The numbers in column 3 for  $n_s=2$  include the following production schemes:  $p\bar{p}+-$ ,  $n\bar{n}+-$ ,  $p\bar{p}+-0$ ,  $n\bar{n}+-0$ , and  $p\bar{n}+-0$ . (The +, -, and 0 refer to the charges of the created mesons.)