

the cooperative effort of the entire staff of the 60-inch cyclotron group, and the continued interest of Professor Glenn T. Seaborg and Professor Ernest O. Lawrence in this program.

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- ¹ L. W. Alvarez, *Phys. Rev.* **58**, 192 (1940).
² R. Condit, *Phys. Rev.* **62**, 301 (1942).
³ York, Hildebrand, Putnam, and Hamilton, *Phys. Rev.* **70**, 446 (1946).
⁴ Miller, Hamilton, Putnam, Haymond, and Rossi, *Phys. Rev.* **80**, 486 (1950).
⁵ J. F. Miller, *Phys. Rev.* **83**, 1261 (1951).
⁶ Ghiorso, Thompson, Street, and Seaborg, *Phys. Rev.* **81**, 154 (1951).
⁷ C. A. Tobias, *Phys. Rev.* **85**, 764 (1952).
⁸ Chackett, Fremlin, and Walker, *Proc. Phys. Soc. (London)* **A66**, 495 (1953).
⁹ D. Walker and J. H. Fremlin, *Nature* **171**, 189 (1953).
¹⁰ L. D. Wyly and A. Zucker, *Phys. Rev.* **89**, 524 (1953).
¹¹ J. M. Hollander, University of California Radiation Laboratory Un-
classified Report UCRL-1396, July, 1951 (unpublished).
¹² R. R. Wilson, *Phys. Rev.* **56**, 459 (1939).
¹³ L. Marquez and I. Perlman, *Phys. Rev.* **78**, 189 (1950).

Reactions of U^{238} with Cyclotron-Produced Nitrogen Ions*

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THE acceleration of $N^{14}(+6)$ ions with the Berkeley Crocker Laboratory 60-inch cyclotron¹ has made it possible to study nuclear reactions of these ions with U^{238} .

The following transmutation products have been observed: $99^{247(?)}$, 99^{246} , Cf^{244} , Cf^{246} , $Cf^{247(?)}$, Cf^{248} , Bk^{243} , and other berkelium isotopes not yet identified. The identification of the elements was definitely established by their carrying on lanthanum fluoride precipitates and by their order of elution from a Dowex-50 ion exchange column.

The observed nuclear properties of these nuclides are summarized in Table I.

The nuclides Cf^{244} , Cf^{246} , Cf^{248} , Bk^{243} , and Bk^{245} have previously been observed in this laboratory.²⁻⁴

The yields of the transcurium nuclides were low even though bombardment currents of 0.1 microampere of $N^{14}(+6)$ ions of energy greater than 100 Mev were available. In three separate experiments a total of 40 alpha-emitting atoms of the 7.3-minute

TABLE I. Nuclides produced by U^{238} plus N^{14} ions.

Nuclide	Half-life	Radiation	Alpha energy (Mev)	Remarks
$99^{247(?)}$ 99^{246}	7.3 min minutes	EC(?), α EC	7.35	Observed only through growth of its 1.5-day Cf^{246} daughter
Cf^{244} Cf^{246}	45 min 35.7 hr	α , EC(?) α	7.15 6.75	
$Cf^{247(?)}$ Cf^{248}	\sim 2.7 hr 225 day	EC α	6.26	Observed K x-rays; probably unresolved mixture of Bk^{245} and Bk^{246}
Bk^{243}	4.6 hr	EC, α	6.72 (30%) 6.55 (53%) 6.20 (17%)	
Bk	days	EC		

isotope of element 99 were observed to decay in the ion exchange column fraction immediately preceding californium, namely the eka-holmium position. Thus, the element identification is certain though the mass number can only be inferred on the basis of nuclear systematics. By observations of the abundant fission product activity it was found that almost all of the nuclear reactions of nitrogen ions with U^{238} resulted in fission much as in the case of carbon-ion bombardment of the same nucleus.

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¹ Rossi, Jones, Hollander, and Hamilton, preceding letter [*Phys. Rev.* **93**, 256(L) (1954)].

² Hollander, Perlman, and Seaborg, *Revs. Modern Phys.* **25**, 469 (1953).

³ E. K. Hulet, Ph.D. thesis, University of California Radiation Laboratory Un-
classified Report UCRL-2283, July, 1953 (unpublished).

⁴ There is unpublished information relevant to element 99 at the University of California, Argonne National Laboratory, and Los Alamos Scientific Laboratory. Until this information is published the question of the first preparation should not be prejudged on the basis of this paper.