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TRANSCURIUM ISOTOPES PRODUCED IN THE NEUTRON IRRADIATION OF PLUTONIUM

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We have succeeded in producing isotopes of three transcurium elements by the irradiation of the starting material Pu^{239} in the Materials Testing Reactor. The heaviest elements were separated completely from plutonium, fission products, americium, and curium by methods involving combinations of precipitation and ion exchange.[1-4] In the element 97 (berkelium) fraction, soft beta particles were observed. In the californium fraction, alpha particles of three different energies were observed, namely, about 6.15 Mev, 6.05 Mev, and 5.8 Mev. In the fraction just preceding the californium in elution from the hot Dowex-50 resin column, specifically the element 99 fraction,[5] alpha particles of 6.6 Mev energy were observed. The amount of activity observed in this fraction was extremely small, nevertheless, its assignment to element 99 is regarded as certain. All of these isotopes have half-lives longer than one week.

The berkelium isotope which decays by the emission of soft beta particles is probably Bk^{249}. Other work[6] has indicated that Bk^{247} is probably a relatively short-lived isotope which decays by electron capture to Cm^{247} which is beta stable. Therefore the lightest curium isotope which decays to berkelium would be Cm^{249}. The assignment to Bk^{249} is also reasonable since its radiations should be very soft whereas Bk^{248} or Bk^{250} (both odd-odd isotopes) would be expected to emit energetic radiation.

On the basis of this assignment, it is interesting to note that there are no beta-stable berkelium isotopes.

The californium isotope or isotopes emitting the above mentioned alpha particles must be heavier than 248. From alpha systematics, the alpha half-lives corresponding to the measured energies should range from a few years to several hundred years.[7]

The isotope of element 99 emitting 6.6 Mev alpha particles is logically assigned as 99^{253}. A reasonable half-life estimated from systematics, assuming a hindrance factor of ten, would be very roughly a month.

The isotopes mentioned here were all produced as a result of combinations of successive neutron captures and beta decays. A possible sequence leading to the production of 99^{253} might be the following:[8]

$$Pu^{239}(n,\gamma)Pu^{240}(n,\gamma)Pu^{241}(n,\gamma)Pu^{242}(n,\gamma)Pu^{243}$$

$$\downarrow \qquad\qquad \uparrow \qquad\qquad \downarrow$$

$$Am^{241}(n,\gamma)Am^{242}(n,\gamma)Am^{243}(n,\gamma)Am^{244}$$

$$\downarrow \qquad\qquad\qquad\qquad \downarrow$$

$$Cm^{242}(n,\gamma)Cm^{243}(n,\gamma)Cm^{244}$$

$$Cm^{244}(n,\gamma)Cm^{245}(n,\gamma)Cm^{246}(n,\gamma)Cm^{247}(n,\gamma)Cm^{248}(n,\gamma)Cm^{249}$$

$$\downarrow$$

$$Bk^{249}$$

$$Bk^{249}(n,\gamma)Bk^{250}$$

$$\downarrow \qquad\qquad \downarrow$$

$$Cf^{249}(n,\gamma)Cf^{250}(n,\gamma)Cf^{251}(n,\gamma)Cf^{252}(n,\gamma)Cf^{253}$$

$$\downarrow$$

$$99^{253}$$

There is classified information relevant to element 99 at Berkeley, Argonne National Laboratory, and Los Alamos Scientific Laboratory.

Until this information can appear in the open literature the question of the first preparation should not be prejudged on the basis of this paper or the preceding one.[5]

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[1] Thompson, Ghiorso, and Seaborg, Phys. Rev. 80, 781 (1950).

[2] Thompson, Street, Ghiorso, and Seaborg, Phys. Rev. 80, 790 (1950).

[3] Thompson, Cunningham, and Seaborg, J. Am. Chem. Soc. 72, 2798 (1950).

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[5] Ghiorso, Rossi, Harvey, and Thompson, Phys. Rev. (in press).

[6]E. K. Hulet, Ph. D. thesis, University of California Radiation Laboratory Report UCRL-2283 (August 1953).

[7]Perlman, Ghiorso, and Seaborg, Phys. Rev. 77, 26 (1950).

[8]G. T. Seaborg, University of California Radiation Laboratory Report UCRL-1942 (March 1952).