Long-Lived Isomer of Np^{236}

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A long-lived isomer of Np^{236}, identified by chemical and mass spectrometric means, has been prepared by the $U^{238}(d,4n)$ reaction. The alpha half-life of this isomer has not been established, but a lower limit of 5000 years has been placed on the beta half-life. The cross section for the $U^{238}(d,4n)Np^{236,236*}$ reaction for 21.6-Mev deuterons has been calculated to be approximately 35 millibarns. A slow-neutron fission cross section of 2800 barns has been determined for the long-lived isomer.

EVIDENCE for the existence of a long-lived isomer of Np^{236} was first obtained from a deuteron bombardment of uranium metal in which the isotopic ratio U^{235}/U^{238} was reduced to 1/2800.[1] A solid metal disk was bombarded for 1200 microampere-hours with 22-Mev deuterons in the Berkeley 60-inch cyclotron. Two successive layers (three and five mils, respectively) were milled from the face of the target and dissolved in acid. Neptunium was isolated chemically from each solution. Slow neutron fission measurements made upon the individual neptunium fractions showed the fissionability to decrease with a two-day half-life characteristic of Np^{238} beta decay. In addition to this fissionability, a long-lived fissionable material was found in the three-mil layer of the target but not in the five-mil layer. This long-lived fissionable material persisted in the neptunium fraction even after further chemistry had been performed which should have removed any other element. Since the slow-neutron fission cross section of Np^{237} was too small to account for the observed number of fissions and since the long-lived fissionability was found only in the upper three-mil layer of the target, it was assumed that this fissionability was due to a Np^{236} isomer formed by a $(d,4n)$ reaction. No fissionability characteristic of 22-hour Np^{236} was found because of its relatively short half-life and low yield.

In the present experiment, a 100-milligram target of U_3O_8 having an isotopic ratio U^{235}/U^{238} of 1/3190 was evenly deposited over an area of seven square centimeters and bombarded for 2700 microampere-hours with 21.6-Mev deuterons in the Argonne 60-inch cyclotron. After bombardment, the uranium was dissolved in acid and allowed to remain undisturbed for fifteen months. At the end of this period, neptunium was chemically separated, purified, and isotopically analyzed in a 12-in., 60° mass spectrometer using a multiple-filament surface ionization source.[2] Masses 236 and 237 were observed; the mole ratio 236/237 was found to be 0.062 ± 0.001 and to remain constant during analysis. This constant ratio, together with the chemical separation in which the quantities of Pu^{236} and U^{236} were reduced below the detection limit ($\sim10^{-13}$ grams) of the mass spectrometer, showed the 236 mass to be an isotope of neptunium.

A total of approximately 50 alpha counts per minute was isolated in the neptunium fraction. In a preliminary pulse analysis of this fraction no alpha energy other than that attributed to Np^{237} was apparent. This indicated either that the alpha activity of long-lived Np^{236} is low because of a very long alpha half-life or that the alpha-decay energy is very similar to that of Np^{237}. A beta half-life of ≥5000 years has been calculated for the Np^{236} isomer on the basis of a beta-to-alpha ratio of ~25 found in the neptunium fraction and by assuming the beta activity to be due to Np^{236} and the alpha activity due to Np^{237}.

With an electron capture-to-beta ratio of two[3] for the decay of 22-hour Np^{236} it was calculated, on the basis of the observed Pu^{236} yield, that $\frac{1}{6}$ of the product formed in the $U^{238}(d,4n)Np^{236,236*}$ reaction was the long-lived isomer. This may have been formed directly and/or by isomeric transition of the 22-hour Np^{236}. The cross section for the $U^{238}(d,4n)Np^{236,236*}$ reaction for 21.6-Mev deuterons is approximately 35 millibarns.

Three Np^{236} samples subjected to different degrees of chemical purification were tested for thermal neutron fissionability in the Argonne CP-3′ heavy water pile.[4] The fission-to-alpha ratio for each of the neptunium samples was the same, indicating chemical purity. Again by assuming that all the alpha activity was due to Np^{237}, the fission cross section of Np^{236} (long-lived) was found to be approximately 2800 barns.

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[1] Studier, Hopkins, Ghiorso, and Bentley, Atomic Energy Commission Report CF-3762, 1947; reviewed by G. T. Seaborg, *The Actinide Elements* (McGraw-Hill Book Company, Inc., New York, 1954), National Nuclear Energy Series, Plutonium Project Record, Vol. 14A, Div. IV, Chap. 11.

[2] M. G. Inghram and W. A. Chupka, Rev. Sci. Instr. 24, 518 (1953).

[3] D. A. Orth and G. D. O'Kelley, Phys. Rev. 82, 758 (1951).

[4] The method of fission counting is described by A. Ghiorso and W. C. Bentley, *The Transuranium Elements* (McGraw-Hill Book Company, Inc., New York, 1949), Paper No. 22.29, National Nuclear Energy Series, Plutonium Project Record, Vol. 14B, Div. IV.