The Thermal Neutron Capture Cross Sections of Pa^{231} and Pa^{232}

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The neutron capture cross section of Pa^{231} has been determined to be 293 barns, the largest uncertainty in this determination being due to the uncertainty in the half-life of U^{232} and being of the order of 15 percent. The neutron capture cross section of Pa^{232} was determined to be about $40\binom{+40}{-20}$ barns.

THE cross section of Pa^{231} for capture of pile neutrons has been determined by the measurement of the U^{232} formed by the beta-decay of the Pa^{232} initially formed. Previous values obtained either as above or by direct measurement of the Pa^{232} have ranged from 140 to 230 barns.[1]

A two-milligram sample of Pa^{231} was irradiated in the Hanford pile along with 4.52 μg of Np^{237} as a flux monitor. The amount of Pu^{238} formed was determined radiometrically. The total neutron flux was then calculated from the amount of Pu^{238} formed and using the following constants: Np^{237} half-life, 2.20×10^6 years;[2] Pu^{238} half-life, 92 years;[3] and the capture cross section of Np^{237}, 172 barns.[4] After the sample had cooled sufficiently for essentially all of the Pa^{232} to decay (16 half-lives), the sample was dissolved in $10M$ HNO_3 containing a little HF. An aliquot of this mixture was alpha-counted and pulse analyzed for U^{232} at this stage. The fluoride was removed by fuming with perchloric acid, and the uranium was isolated by exhaustive extraction with double volumes of ether from a solution $1M$ in HNO_3 and saturated with NH_4NO_3. There was less than 1 percent by activity of the original U^{232} left in the aqueous solution, as determined by pulse analysis. The uranium was re-extracted into water, and an aliquot was plated and its rate of alpha-emission determined. As pulse analysis showed this sample to be $\sim$95 percent U^{232}, the weight could be determined. This value checked that obtained from the assay of the original solution. Assuming that all of the Pa^{232} had decayed to U^{232} and using a value for the half-life of U^{232} of 70 years,[5] a value of the capture cross section for Pa^{231} was determined as 293 barns. The largest uncertainty in this determination is due to the uncertainty in the half-life of U^{232} and is of the order of 15 percent.

An estimate of the capture cross section for the second-order reaction, $Pa^{232}(n,\gamma)Pa^{233}$, was made. After the uranium was removed from the original dissolver solution, the protactinium in this solution was purified by extraction into di-isopropyl ketone from a solution $6N$ in HNO_3 and further purified by extraction from a $10N$ HNO_3 solution with thenoyltrifluoroacetone in benzene.

An attempt to resolve the G-M activity of the protactinium fraction failed, and the amount of Pa^{233} present was estimated by following the decay of the sample. As the counting efficiency was not known, this was determined by counting a purified sample of Pa^{233} under the same conditions and estimating its weight by following the increase in fissionability due to the U^{233} daughter. With due corrections for the counting efficiency, Pa^{231} blank, and other long-lived GM activity, an estimate could be made of the Pa^{233} formed. Assuming a constant flux during the irradiation, a value is estimated for the Pa^{232} capture cross section of $40\binom{+40}{-20}$ barns.

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[1] Clinton Laboratories Report CL-RWS-20, 1946 (unpublished); A. H. Jaffey and Q. Van Winkle, Argonne National Laboratory, Report ANL-4283, 1949 (unpublished); recalculated from data in a report by Elson, Van Winkle, Bentley, and Ghiorso [Argonne National Laboratory Report CF-3795, 1947 (unpublished)].

[2] L. B. Magnusson and T. J. LaChapelle, J. Am. Chem. Soc. **70**, 34 (1948).

[3] Seaborg, James, and Ghiorso, The Transuranium Elements: Research Papers (McGraw-Hill Book Company, New York, Inc., 1948), p. 226, National Nuclear Energy Series, Plutonium Project Record, Vol. 14B, Div. IV.

[4] A. H. Jaffey and L. B. Magnusson, Argonne National Laboratory Report ANL-4030, 1947 (unpublished).

[5] James, Florin, Hopkins, and Ghiorso, reference 3, Paper No. 22.8.