process predicted by the model might be expected to have an $A^{\frac{1}{3}}$ dependence. In going from Sn to Pb, $A^{\frac{1}{3}}$ increases by 20 percent. This agrees with the experimental evidence that the Pb total cross section is 15 percent greater than the Sn cross section.

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The Half-Life of Lanthanum-140†

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Carrier-free lanthanum-140 was separated from barium-140 by a double barium nitrate precipitation from 80 percent nitric acid, using inert barium carrier. The half-life, determined by beta counting, was found to be 40.224±0.020 hours over a period of 574 hours.

IN a separate communication,[1] the authors describe a method for the separation of carrier-free lanthanum-140 from barium-140. A modification of this procedure was used to prepare a high-purity, high-specific activity product which would be suitable for use in a half-life determination.

As a preliminary purification, 0.5 gram of barium nitrate, spiked with approximately one millicurie of barium-140,[2] was precipitated from 80 percent nitric acid, and the filtrate was discarded. To remove possible strontium isotopes, the barium nitrate was redissolved, 10 milligrams of strontium carrier was added, and barium chromate was precipitated from homogeneous solution.[3] The filtrate, containing strontium chromate, was discarded. The barium chromate was redissolved, additional strontium was added, and barium chromate was again precipitated. The barium chromate was converted to barium nitrate (by precipitation from 70 percent nitric acid to remove chromate ion and residual strontium carrier).

The purified barium nitrate was set aside to allow time for the growth of lanthanum-140. After five days, the barium nitrate was precipitated from 80 percent nitric acid, and the filtrate, containing 85 percent of the lanthanum-140 and approximately 0.03 percent of the barium-140, was evaporated to dryness. The residue was redissolved in water, inert barium nitrate was added, and the precipitation was repeated. The filtrate was evaporated to dryness and redissolved in four milliliters of dilute nitric acid. The final solution contained approximately 0.7 millicurie of lanthanum-140, 10^{-7} millicurie of barium-140, and 50 micrograms of inert barium.

Since radium and lead isotopes, if present in the original barium-140, might have passed through the purification process, samples of the purified barium nitrate and the final lanthanum-140 solution were counted in an air-ionization parallel plate alpha counter having a background of less than one count per minute. No alpha counts were detected in either fraction or in any of the samples used for the half-life determination.

The instrument used for beta counting was a 2π proportional counter[4] having a resolution time of 0.1 microsecond. Samples were inserted in the windowless counting chamber, and the chamber was flushed thoroughly with a mixture of 90 percent methane and 10 percent argon. The gas flow was maintained throughout the counting period. The instrument was standardized daily with a plutonium standard sample, and the background, which varied between 50 and 75 counts per minute, was determined before and after each sample was counted. Background and coincidence corrections were made for all counting data. Each measurement was the average of two successive five-minute counts which agreed within one percent.

The upper limit of the instrument was approximately 350 000 counts per minute, and an arbitrary lower limit of approximately 1000 counts per minute was set to avoid loss of counting precision. With these restrictions, no single sample could be counted for more than eight half-lives. Accordingly, a special technique was used by which the lanthanum-140 decay could be followed for a much longer period.

Five samples of the lanthanum-140 solution were mounted on stainless steel disks and evaporated to dryness. The first sample contained approximately

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[1] M. L. Salutsky and H. W. Kirby, Anal. Chem. (to be published).

[2] Obtained from Isotopes Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

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[4] Nuclear Measurements Corporation Model PC-1 alpha-beta-gamma counter.

TABLE I. The half-life of lanthanum-140.

Age of sample[a] (hours)	Starting counts/minute	Half-life (hours)
28–142	6 000	40.2694±0.2754
46–214	106 000	40.1481±0.0276
148–244	59 000	40.2390±0.0552
220–478	316 000	40.1969±0.0341
310–574	308 000	40.2845±0.0226
	Grand mean	40.224 ±0.015 (int. p.e.) 0.020 (ext. p.e.)

[a] Time from final separation to beginning and end of counting.

10 000 counts per minute, and each subsequent sample contained from five to ten times as much lanthanum-140 as the preceding one. The fifth sample contained approximately 50 microcuries of lanthanum-140.

Two samples were counted at the beginning and end of each working day. Whenever a sample decayed below 350 000 counts per minute, it replaced the weaker of the two samples currently being counted. Counting of the final sample was discontinued when it decayed below 1000 counts per minute. Thus, each segment of the decay curve of lanthanum-140 was represented by two separate, overlapping samples. If a long-lived impurity had been present to a significant degree, its presence would have been made evident by a progressive increase in the half-life.

For various practical reasons, it was not found possible to adhere strictly to the plan of counting each sample for eight half-lives, but the technique of overlapping segments made it possible to follow the lanthanum-140 decay with confidence for a period of over 14 half-lives.

The half-life and probable error for each sample was determined by the method of least squares (Table I). The grand mean for the five determinations, weighted inversely as the squares of their probable errors, was 40.224±0.020 hours (external probable error). There was no systematic deviation in any sample, or in the group of five samples, to indicate the presence of a long-lived impurity.

A sixth sample, representing approximately 0.3 millicurie of the original lanthanum-140, was counted beginning 484 hours after purification. The sample had an apparent half-life of 39.8±0.1 hours, but was found to be increasing the counter background by 250 to 900 counts per minute, indicating that the flow of quenching gas through the chamber was causing significant loss of material from the sample mount. On this basis, as well as by Chauvenet's criterion,[5] the sample was excluded from the grand mean.

The currently accepted half-life of lanthanum-140 is 40.0 hours[6] (±0.3 hour,[7] ±0.5 hour,[8] ±0.1 hour[9]), based on work done with neutron- or deuteron-irradiated lanthanum-139. The half-life reported here falls well within the limits of experimental error assigned to two of these determinations.[7,8] In the third case,[9] the data given are insufficient for critical evaluation of the work. However, the authors reported a 2.9-Mev gamma energy which they believed might be caused by an unidentified impurity.

[5] A. G. Worthing and J. Geffner, *Treatment of Experimental Data* (John Wiley and Sons, Inc., New York, 1943), pp. 170–171.

[6] *Nuclear Data, National Bureau of Standards Circular 499* (U. S. Government Printing Office, Washington, D. C., 1950), p. 169, and Supplement I (April 25, 1951), p. 30.

[7] Weimer, Pool, and Kurbatov, Phys. Rev. **63**, 67 (1943).

[8] Ballou, Rubinson, and Glendenin, *Radiochemical Studies: The Fission Products* (McGraw-Hill Book Company, Inc., New York, 1951), Paper No. 165, National Nuclear Energy Series, Plutonium Project Record, Vol. 9, Div. IV.

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