PHYSICAL REVIEW VOLUME 101, NUMBER 6 MARCH 15, 1956

Decay of Sb^{127} and Sb^{129}†*

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(Received December 14, 1955)

The techniques of scintillation spectrometry have been applied to the study of the decay of Sb^{127} and Sb^{129}. Both decays were found to be too complex to permit complete analysis in the present experiments, but a number of beta- and gamma-ray transitions were measured for each nuclide. In the decay of 93-hour Sb^{127} three beta-ray groups and eight gamma-ray transitions were measured. Coincidences were observed among several pairs of these transitions. In the 9.2-hour Sb^{129} four gamma rays were observed and measured and the end-point energy of the most energetic beta transition was determined.

INTRODUCTION

The decays of the antimony isotopes of mass numbers 127 and 129 have received very little study. They were both first observed as products of uranium fission by Abelson[1] who measured the half-lives as 80 and 4.2 hours, respectively. Later studies on Sb^{127} showed the half-life to be 93 hours[2] and absorption measurements gave 1.2 Mev as the maximum beta-ray energy and 0.72 Mev as the gamma-ray energy.[2] No energy measurements have been reported on Sb^{129}.

Since photoproton reactions on stable isotopes of tellurium would give these antimony activities, it was decided to study their decay following their production by the Iowa State College 70-Mev synchrotron.

SOURCE PREPARATION

The antimony activities were obtained by irradiating natural tellurium metal at the maximum energy of the synchrotron x-ray beam, 70 Mev. The tellurium metal was dissolved in hot H_2SO_4, together with a small amount of antimony metal as carrier. The solution was diluted and Na_2SO_3 was added to precipitate the tellurium. The antimony was precipitated as Sb_2S_5 and H_2S. As a purification step the sulfide was redissolved in concentrated HCl, the solution was filtered, and Sb_2S_5 was reprecipitated. The sources were prepared by filtering the Sb_2S_5.

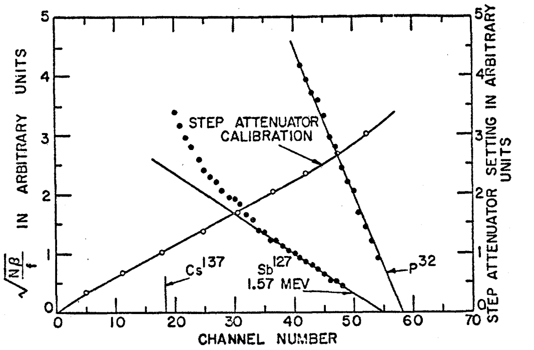

Fig. 1. Kurie plot of antimony-127.

EQUIPMENT AND PROCEDURE

The scintillation spectrometer, pulse-height recorder, and dot counter used in the measurements and the procedure used for measurement and calibration are the same as those described in an earlier paper on the tellurium isotopes produced in the same type of irradiation.[3] The spectrometer and pulse-height analysis system have been described in earlier publications.[4–6]

In order to obtain sufficient Sb^{127} activity to study, the source was mounted inside the synchrotron donut on the back of the electron gun. Thin tantalum sheets were placed in front of the target to serve as x-ray radiators, and about 15 hours of irradiation time were used. The Sb^{129} formed in the process was permitted to decay out.

The Sb^{129} activity was obtained by irradiating five grams of tellurium metal for four hours outside of the

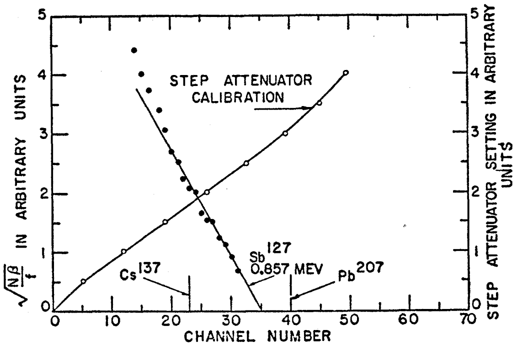

Fig. 2. Kurie plot of antimony-127 beta ray in coincidence with the 0.674-Mev gamma ray.

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† Contribution No. 422. Work was performed in the Ames Laboratory of the U. S. Atomic Energy Commission.

* Based on a thesis submitted by one of the authors (MCD) to Iowa State College in partial fulfillment of the requirements for a Ph.D. degree.

[1] P. H. Abelson, Phys. Rev. **56**, 1 (1939).

[2] N. R. Sleight and W. H. Sullivan, *Radiochemical Studies: The Fission Products* (McGraw-Hill Book Company, Inc., New York, 1951), p. 928.

[3] Day, Eakins, and Voigt, Phys. Rev. **100**, 796 (1955).

[4] S. Johansson, Atomic Energy Commission Report No. ISC-431 (unpublished).

[5] F. T. Boley and D. J. Zaffarano, Phys. Rev. **84**, 1059 (1951).

[6] Hunt, Rhinehart, Weber, and Zaffarano, Rev. Sci. Instr. **25**, 268 (1954).

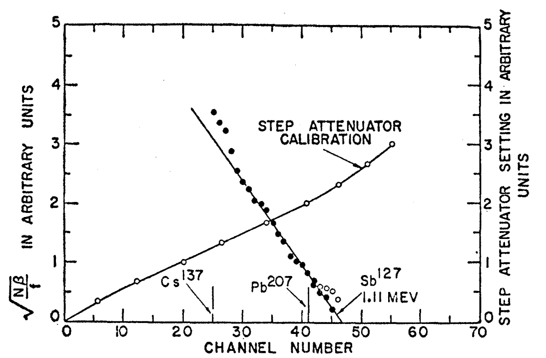

FIG. 3. Kurie plot of antimony-127 beta ray in coincidence with the 0.456-Mev gamma ray.

donut and using it immediately while the ratio of Sb^{129}/Sb^{127} activities was highest.

RESULTS

Antimony-127

The decay of antimony-127 was found to be complex. Analysis of the Kurie plot of the total beta-ray spectrum indicated at least three beta-ray groups, and the gamma-ray spectrum showed eight gamma rays with the major transitions at 0.240, 0.456, and 0.674 Mev. The beta-ray and gamma-ray data are summarized in Table I.

Figure 1 shows a typical Kurie plot for the high-energy beta-ray group from which the end point was determined to be 1.57±0.03 Mev. Gamma-beta coincidence measurements were used to determine the energies of the less energetic beta transitions. From these it was found that in coincidence with the 0.674-Mev gamma ray there is a 0.86±0.02-Mev beta transition and in coincidence with the 0.456-Mev gamma a 1.11±0.03-Mev beta. The Kurie plots of these two beta-rays are shown in Figs. 2 and 3.

The relative intensities of the beta-ray transitions shown in Table I were determined by back-extrapolating the Kurie plots to zero energy and reconstructing the energy distribution curves from the Kurie plots as shown in Fig. 4.

TABLE I. Radiations of antimony-127 and antimony-129.

Isotope	Beta-ray end point (Mev)	Estimated intensity of β rays %	Log ft	Gamma-ray energy (Mev)
Sb^{127}	1.57±0.03	30	8.1	0.058±0.010
	1.11±0.03	20	7.8	0.185±0.008
	0.86±0.02	50	7.0	0.240±0.003
				0.417±0.008
				0.456±0.004
				0.563±0.005
				0.674±0.005
				0.764±0.010
Sb^{129}	1.87±0.05	20	7.4	0.165±0.005
				0.308±0.004
				0.534±0.003
				0.788±0.005

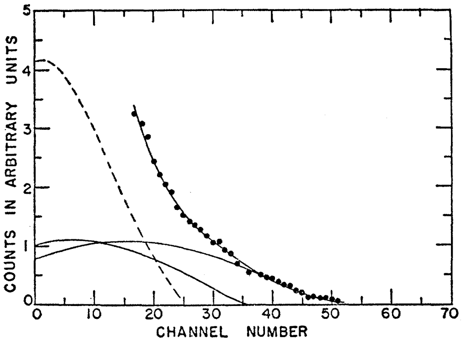

FIG. 4. Relative intensities of antimony-127 beta rays.

Antimony-129

The total beta-ray spectrum of antimony-129 indicated several groups. However, it was only possible to determine the end-point energy of the highest energy group. This was found to be 1.87±0.05 Mev. A typical Kurie plot is shown in Fig. 5.

The gamma transitions are listed in Table I; they are all relatively major transitions.

DISCUSSION

The logft value for the highest energy beta-ray transition in Sb^{127} was calculated to be 8.1. This would indicate that the transition might be of the special class of first forbidden transitions with $\Delta I=2$ and a change in parity. A number of these transitions have been observed[7] which have a unique shape that differentiates them from the ordinary first forbidden transition with $\Delta I=0$ or ± 1 and a change in parity.

If the 1.57-Mev beta ray proceeds from the ground state of Sb^{127}, which has an assigned level of $g_{7/2}$, to the 113-day isomeric state of Te^{127} with a level assignment of $h_{11/2}$,[8] the selection rules for this type of first forbidden transition would be satisfied. Although the Kurie plot does not appear to have a unique shape, it

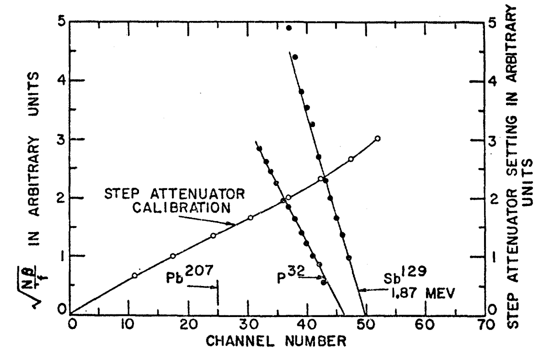

FIG. 5. Kurie plot of antimony-129.

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[7] C. S. Wu, Revs. Modern Phys. 22, 386 (1950).

[8] M. Goldhaber and R. D. Hill, Revs. Modern Phys. 24, 179 (1952).

is questionable if such a shape could be detected by the methods of scintillation spectrometry in a low-intensity transition.

The logft value was calculated to be 7.4 for the 1.87-Mev beta transition in Sb^{129}. This is in the range for first forbidden transitions with $\Delta I=0$ or ± 1 and a change in parity. The ground state of Sb^{129} has an assigned level of $g_{7/2}$ and the 34-day and 72-minute isomers of Te^{129} appear to occupy $h_{11/2}$ and $d_{3/2}$ levels respectively.[8] This would indicate that the 1.87-Mev beta ray of Sb^{129} does not go directly to either of these two levels, but proceeds through a higher excited level and a gamma transition to one or the other of the tellurium isomers.

Since the complete disintegration schemes of these isotopes could not be obtained without many additional measurements, it is not possible at this time to make any definite proposals about the nature of the lower-energy beta transitions or to assign spins to the various levels involved in the complex decay processes.

PHYSICAL REVIEW VOLUME 101, NUMBER 6 MARCH 15, 1956

Search for Possible Naturally Occurring Isotopes of Low Abundance

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(Received July 8, 1955; revised manuscript received December 27, 1955)

A systematic search has been made for the existence of previously unobserved naturally occurring isotopes of low abundance. A two-stage mass analyzer was employed. With the exception of Ta^{180}, none were found. The improved abundance sensitivity of the two-stage spectrometer, however, allowed determinations of lower experimental "upper limits" to be placed on a large number of isotopes. The elements, sodium, aluminum, scandium, niobium, and cesium were confirmed to be monoisotopic. A comparison has also been made of abundance measurements obtained with this instrument to those obtained in previous investigations.

INTRODUCTION

THERE are at least two reasons for continued interest in isotopic abundance measurements of the naturally occurring elements. First, certain hypotheses concerning nuclear structure can be tested for consistency relative to the experimentally determined isotopic constitution of matter. Second, and of increasing importance, is the interest in measuring the radiative capture of many elements for various neutron spectra. In many instances, it is desirable to measure the buildup of a very small number of nuclei. It is thus necessary that very low experimental "upper limits" be placed on the existence of these nuclei occurring in nature.

Accordingly, we have made such measurements as could be readily made on stable isotopes with the instrumentation which has been developed for nuclear work in this laboratory during the past year.

APPARATUS

The instrument used for this survey was a two-stage mass spectrometer with two 90-degree, 12-inch radius of curvature magnetic sectors arranged in tandem. It is important to note that for such an instrument, abundance sensitivity, rather than resolution alone, is a figure of merit. The abundance sensitivity is defined as the reciprocal of the fractional number of ions of mass M which arrive and are detected at the $M+1$ mass position in the image focal plane. In order for an instrument to have a high abundance sensitivity, e.g., 10^6, it is of course necessary for the detector to have a range of 10^6.

A unique feature of this instrument is that only particles of a single mass at a time are allowed to pass through an intermediate slit, thus minimizing the effect of small-angle elastic scattering within the analyzer tube. For an intermediate slit which is small compared to the dispersion, the fractional number F of ions of mass M, which are scattered to the mass $M+1$ position for a single analyzer, is reduced to F^2. Details of this instrument, which is diagrammatically shown in Fig. 1, are discussed elsewhere.[1]

It was necessary, for some of the measurements reported here, to observe exceedingly small beam currents due to limited positive ion emission. A twenty-stage Allen-type multiplier was employed, not as a dc amplifier, but as a counter[2] of discrete positive ions. A normal background counting rate, due to thermionic electrons emitted from the first dynode only, corresponds to about 5×10^{-20} ampere. Currents in the 10^{-19} ampere range were thus observable.

SAMPLE PREPARATION AND ION PRODUCTION

In an investigation of this type where the primary purpose is to determine new limits on isotopic ex-

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* Operated for the U. S. Atomic Energy Commission by the General Electric Company.

[1] F. A. White and T. L. Collins, Appl. Spectroscopy 8, No. 4, 169 (1954).

[2] F. A. White and T. L. Collins, Appl. Spectroscopy 8, No. 1, (1954).