Activation Cross Sections Measured with Antimony-Beryllium Photoneutrons

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Activation cross sections for 15 isotopes have been measured by means of an antimony-beryllium photoneutron source. The cross sections have been determined relative to the values of the thermal neutron activation cross sections of each substance.

I. INTRODUCTION

PHOTONEUTRON sources[1] which will yield a sufficient number of neutrons for activation cross-section measurements will degrade the neutron energies sufficiently to cause a spread of 20 to 25 percent in energy. An electrostatic accelerator using the $Li^7(p,n)Be^7$ reaction to yield[2,3] 35-kev neutrons at 120° from a 10-kev thick lithium target, would give nearly the same spread over a cone of only 5° half-angle. Therefore, at 35 kev, the Sb—Be source competes favorably with an electrostatic accelerator as a neutron source for activation cross-section measurements. In addition, a photoneutron source used in this manner frees the accelerator for use in other experiments. For these reasons a program of activation cross-section measurements with Sb—Be photoneutrons has been undertaken.

II. METHOD

Figure 1 shows the details of the neutron source and foil holder. The aluminum cylinder containing 98 grams of fused antimony was irradiated in the Argonne heavy water pile. After removal from the pile, the source was allowed to cool for two weeks before any measurements were made. The only antimony activity that was important after this length of time was the one from 60-day Sb^{124}.

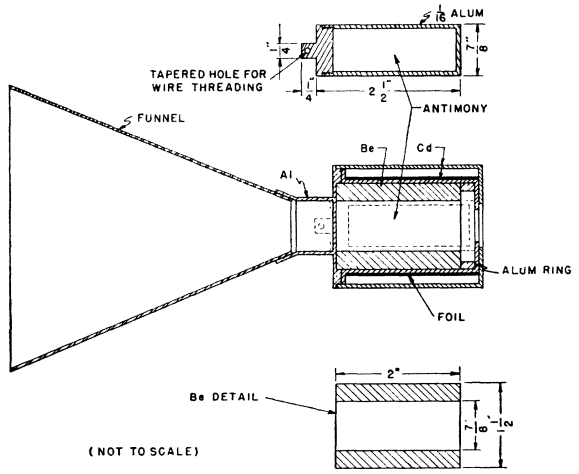

FIG. 1. Sb—Be photoneutron source.

The strength of the neutron source was measured by comparison with a Ra-Be standard by the method described by Hughes.[4] The source yielded 1.5×10^7 neutrons/sec one month after the pile irradiation was ended. The gamma-ray strength was about 8 curies at this time.

The flux from the source varied over the surface of the beryllium. An average flux over the cylindrical surface was determined in the following manner.

A rectangular indium foil placed on the source in the usual foil position shown in the figure was irradiated and then counted. Then an indium disk of the same thickness and covered with cadmium was placed over the flat end of the photoneutron source. The disk was then irradiated and counted. By comparing the saturated activities of the rectangle and the disk of indium, the ratio of the average flux on the two surfaces could be found. It was then assumed that the flux through the cylindrical surface was uniform over this surface and that the fluxes through the flat ends of the source were equal to each other and were also constant over the flat surfaces. With these assumptions, and the measured average flux ratio, an average flux over the region where the foils were irradiated could be calculated.

The irradiations were made outdoors to minimize the number of room scattered neutrons. The apparatus was suspended from a tall tree with the mouth of the funnel pointing upwards. The antimony was raised out of the lead pot in which it was stored and was lowered into the funnel. The whole apparatus was then raised to a height of nearly fifteen feet from the ground. After the irradiation was completed, the antimony was again separated from the beryllium, and the foil was then removed and counted with an efficiency which had been previously determined, as follows.

The counting system was calibrated for each substance in terms of the known[5] thermal neutron activation cross section for the substance. The same foil that was used in the Sb—Be activation was used for calibration purposes, so that the geometrical and absorption effects on the counting efficiency were the same.

The foil and a standard gold foil were irradiated in a

[1] A. Wattenberg, *Photoneutron Sources*, Preliminary Report No. 6, Nuclear Science Series, Division of Mathematics and Physical Sciences, National Research Council.
[2] The energy of the Sb—Be neutrons is still in doubt. See reference 1. Values of 25–35 kev are reported.
[3] Roberts, Hill, and McCammon, Phys. Rev. **80**, 9 (1950).
[4] D. J. Hughes, Nucleonics **6**, 50 (1950).
[5] Seren, Friedlander, and Turkel, Phys. Rev. **72**, 888 (1947).

beam from the thermal column of the Argonne uranium-graphite pile. The gold foil was counted in a counting system that had been standardized. The foil of the substance under study was counted in the experimental counting system. The irradiation was then repeated with cadmium-covered foils. The gold foil measurements allowed one to determine the value of the thermal flux and the measurements on the substance yielded a counting rate due to the thermal neutron activation. By using the value of the known thermal cross section of the substance, the counting efficiency could be found.

In most cases, the materials to be studied were in the form of metal foils. In those instances in which this was not feasible, samples of a powdered salt of the element were prepared as follows.

A backing for the powder was made by bending a sheet of nickel into a cylinder of approximately the same radius as the Geiger counter to be used to detect the activity. This cylinder, of 7.5-cm circumference and 5.5-cm height, was cut, parallel to the axis, into four equal sections.

A known amount of the powder to be studied was then placed on each section, and thoroughly mixed with dilute zapon. The zapon-powder mixture was spread as evenly as possible over one surface of the nickel and allowed to dry. When thoroughly dry, each section was wrapped in wide Scotch Tape to protect the powder surface. The four sections were then mounted on a Scotch Tape backing, which acted as a hinge. This allowed the holder to fit around the counter, the Sb—Be source, or on a flat surface for irradiation at the thermal column of the Argonne uranium-graphite pile.

III. RESULTS

Table I lists the isotopes studied, together with the half-life of the isotope that is formed by the neutron capture, and the results obtained for the natural atom cross section for the reaction at the energy of the Sb—Be neutrons.

The last column of Table I lists the percent error of the measurements, relative to the values given by Seren for the thermal cross section.

TABLE I. Natural atom cross sections for Sb—Be neutrons.

Item	Natural isotope	Half-life of $(A+1)$ isotope	Natural atom cross section (millibarns)	Percent error
1	$_{13}Al^{27}$	2.4 min	1.6	25
2	$_{23}V^{51}$	3.9 min	59	15
3	$_{25}Mn^{55}$	2.59 hr	78	12
4	$_{29}Cu^{65}$	5 min	20	20
5	$_{30}Zn^{68}$	57 min	6.1	20
6	$_{33}As^{75}$	26.8 hr	1.2×10^{3}	20
7	$_{42}Mo^{100}$	14 min	57	30
8	$_{45}Rh^{103}$	4.2 min	2.0×10^{2}	15
9	$_{46}Pd^{108}$	13 hr	3.6×10^{2}	25
10	$_{47}Ag^{107}$	2.3 min	1.1×10^{3}	17
11	$_{49}In^{115}$	54 min	1.0×10^{3}	10
12	$_{51}Sb^{121}$	2.8 day	1.6×10^{3}	20
13	$_{53}I^{127}$	25 min	2.2×10^{3}	20
14	$_{78}Pt^{198}$	31 min	20	10
15	$_{79}Au^{197}$	2.7 day	1.5×10^{3}	15

These errors result from uncertainties in the strength of the standard radium-beryllium source used to calibrate the antimony-beryllium source, from errors in the calibration of the standard counters on which the gold foils were counted, from small variations in geometry in counting the foils and in irradiating them, and from counting statistics. Errors in the half-lives of the isotopes were not considered.

IV. DISCUSSION

Only two of the measurements could be compared with other data that have been obtained on cross sections at this energy. The value obtained for gold is in excellent agreement with that reported by the Los Alamos group.[6] The cross section obtained for aluminum is considerably lower than that given by Henkel and Barschall.[7] The cross sections obtained with Sb—Be neutrons were compared with those published by Beghian and Halban[8] at 200 and 900 kev. As expected, the cross sections obtained with neutrons from the Sb—Be source were generally found to be higher. The two exceptions were aluminum and platinum.

[6] MIDDC-286, edited by K. I. Griesen (unpublished).
[7] R. L. Henkel and H. H. Barschall, Phys. Rev. **80**, 145 (1950).
[8] L. E. Beghian and H. H. Halban, Nature **163**, 366 (1949).