Experimental Determinations of Stopping Powers Using Alpha-Particles of 15 to 37 Mev

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The integrated stopping power relative to aluminum has been measured for copper, silver, tantalum, bismuth, and thorium using alpha-particles of approximately 15- to 28-Mev and 28- to 37-Mev energies. The results are summarized in Table II.

FOR the excitation function work described in the preceding article it was necessary to know the stopping power of bismuth for alpha-particles having energies between 20 and 40 Mev. Since the existing data were not sufficiently accurate for this work an experimental determination of the relative stopping power of various elements from thorium to aluminum was undertaken, using the alpha-particle beam of the Crocker 60-inch cyclotron. For reasons of convenience, only metallic elements were investigated, using aluminum as a standard of comparison. Beryllium, copper, silver, tantalum, bismuth, and thorium were originally chosen for investigation; unfortunately, suitable beryllium foil was unobtainable and this element had to be omitted.

The stopping power was determined in the following way. The range of the alpha-beam in aluminum was first determined. Next an absorber of the element to be investigated was placed in the path of the alpha beam, reducing the energy of the emergent alpha-particles. Then the range in aluminum of the reduced energy alphas was determined. The difference in the two measured ranges in aluminum represents the thickness of aluminum absorber which would produce the same energy loss (at the alpha-particle energy used) as would the absorber under investigation. This procedure was carried out at two alpha-particle energies, approximately 28 Mev and 37 Mev. The results are summarized in Table I.

TABLE I. Absorbers of equivalent stopping power. Each absorber "sandwich" reduced the alpha-beam to half-intensity—the alpha-beam traversing all "sandwiches" from left to right. "Sandwiches" of equivalent stopping power are indicated by equal signs.

62.7 Cu+60.5 Al+33.3 Al=60.5 Al+ 62.7 Cu+34.5 Al=144.0 Al
91.2 Ag+54.1 Al+28.7 Al=54.1 Al+ 91.2 Ag+30.6 Al=144.0 Al
90.9 Ta+65.1 Al+29.1 Al=65.1 Al+ 90.9 Ta+32.0 Al=144.0 Al
112.0 Th+60.8 Al+31.5 Al=60.8 Al+112.0 Th+29.8 Al=144.0 Al
62.7 Cu+60.5 Al+36.5 Al=60.5 Al+62.7 Cu+37.4 Al=147.0 Al
91.2 Ag+54.1 Al+31.6 Al=54.1 Al+91.2 Ag+33.4 Al=147.0 Al
90.9 Ta+65.1 Al+32.4 Al=65.1 Al+90.9 Ta+34.8 Al=147.0 Al
99.0 Bi +60.8 Al+34.5 Al=60.8 Al+99.0 Bi +37.2 Al=147.0 Al
99.1 Bi +59.1 Al+36.5 Al=59.1 Al+99.1 Bi +39.1 Al=147.0 Al
90.9 Th+67.4 Al+33.9 Al=67.4 Al+90.9 Th+36.4 Al=147.0 Al
90.9 Th+66.6 Al+35.0 Al=66.6 Al+90.9 Th+37.5 Al=147.0 Al

EXPERIMENTAL DETAILS

The set of absorbers first used in the experiment consisted of elements that were readily available in the form of thin foil, i.e., aluminum, copper, silver, tantalum, and thorium. The Th absorber was a single foil accurately ground to size. The Al, Cu, Ag, and Ta absorbers were cut to size on a die and consisted of three or more foils each, so that any slight thickness variation in the individual foils would tend to average out. In the second run of this experiment two bismuth absorbers of three foils each were added to the set. Also, thinner thorium foil was secured and two thorium absorbers of three foils each were also added to the set.

The apparatus used was a modification of that described in the preceding article and is shown schematically in Fig. 1. The wheel A contained the absorbers of the various elements to be studied together with suitable aluminum absorbers. Wheel B contained only aluminum absorbers differing by 1.0 mg cm^{-2}. The various alpha-ranges in aluminum were determined in a manner similar to that described in the preceding article. With wheel A in position 1 (112.5 mg cm^{-2} Al in the beam), readings were taken of the current stopped by wheels A and B and of the current to the Faraday cup; this was repeated for several positions of wheel B. In this way the mean beam range in Al was determined. Then wheel A was turned to position 2 (62.7 mg cm^{-2} Cu+60.5 mg cm^{-2} Al) and the currents again read for suitable positions of wheel B. This procedure was followed for a cycle in the order 1, 2, 1, 2, 1, 3, 1, 3, $\cdots$ where the numbers refer to the position of wheel A. Thus the full alpha-energy

TABLE II. Values of the stopping power relative to aluminum computed from the data of Table I.

		Cu	Ag	Ta	Bi	Th
37-Mev	1st run	0.801	0.671	0.548		0.505
alpha-beam	2nd run	0.797	0.672	0.545	0.520	0.501
	Mean	0.799_0	0.671_5	0.546_5	0.520	0.503
Reduced	1st run	0.781	0.650	0.516		0.477
energy beam	2nd run	0.783	0.652	0.518	0.494	0.474
	Mean	0.782	0.651	0.517	0.494	0.475_5

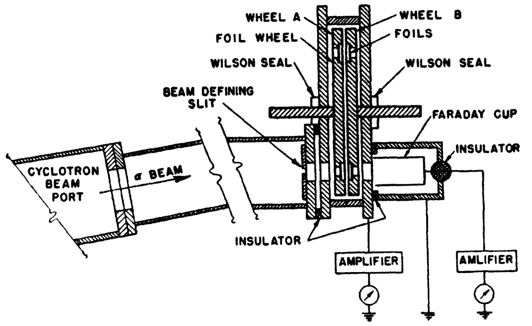

FIG. 1. Schematic diagram of the collimating tube, foil holders, and current amplifiers.

beam range was determined immediately before and after each reduced alpha-energy beam range determination.

To determine the stopping power for alpha-particles of 27 Mev in energy, the stack of foils in each position of wheel A was turned over (i.e., position 2 was changed from 62.7 mg cm^{-2} Cu+60.5 mg cm^{-2} Al to 60.5 mg cm^{-2} Al+6.27 mg cm^{-2} Cu). In this way the energy of the alpha-beam was lowered before the beam entered the various absorbers being investigated.

The α-beam was found to be remarkably constant in energy, the mean range remaining within $\pm\frac{1}{2}$ mg cm^{-2} Al for each cycle of data taken and within ± 1 mg cm^{-2} Al for the entire run. The 3-mg cm^{-2} difference in the range of the alpha-beam used in the two runs can be traced to changes made on the cyclotron. The resultant change in the relative stopping power, however, is too small to be observed, being about 1 part in 500.

RESULTS

The results of the two runs are summarized in Tables I and II. Each sandwich in Table I represents the average of 8 or more determinations. If the relative mass stopping power data of Table II is reduced to stopping power per electron as a function of $\log Z$, the results fall very nearly on a straight line for each energy range. This is shown in Fig. 2. The deviation of thorium, although small, is felt to represent a real effect since the over-all error of this data is estimated to be less than one percent.

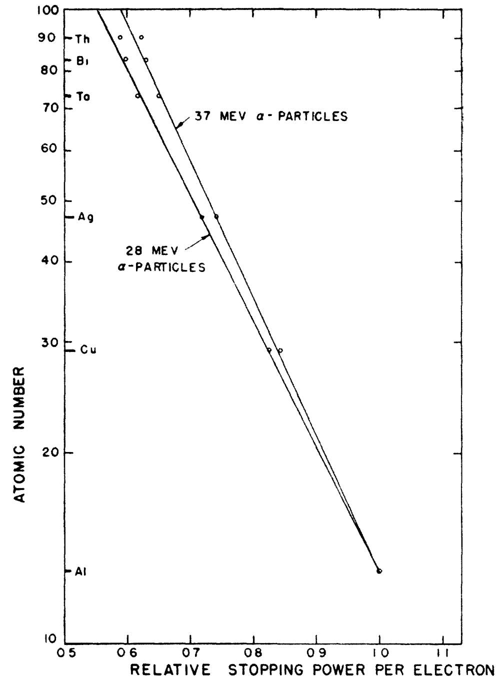

FIG. 2. Relative stopping power per electron as a function of the atomic number Z.

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