Determination of the Maximum Energy of Beta-Rays from Cu 62 by a New Method of Analyzing Absorption Data

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LARGE discrepancies exist between various published values for the end-point energy of the beta-ray spectrum from Cu 62. The published values are 2.6 Mev,[1] 2.5 Mev,[2] and 3.42 Mev.[3] Absorption measurements of the beta-particles from Cu 62 were made by us in an effort to resolve these discrepancies.

It soon became apparent to us that a determination of the end point by visual inspection of the absorption curve or the graphical analyses found in the literature was inaccurate or cumbersome. We have developed a method of analyzing aluminum absorption curves which is an extension of a method given by Widdowson and Champion,[4] embodies some principles of the method of Bleuler and Zünti,[5] and has the advantage of yielding a straight line similar to a Fermi plot.

An aluminum absorption curve for beta-rays may be plotted as in Fig. 1, curve A, where the percent transmission of the rays is plotted against filter thickness in mg/cm². If the gamma-ray background is subtracted, the curve B results.

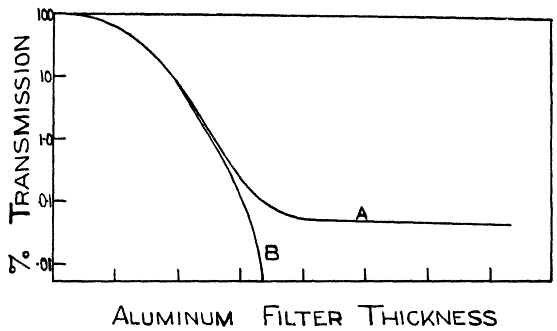

FIG. 1. Aluminum absorption curve for β-rays.

Our method assumes that the lower part of the absorption curve follows a power law of the form:

$$y=K_1(E_0-E)^n, \qquad (1)$$

where y is the fractional transmission, E_0 is the end-point energy, E is the energy of particles just absorbed at a given thickness of filter, and n is a positive constant greater than unity, and either integral or fractional. The expression can be transformed to give:

$$y^{1/n}=K_2(E_0-E). \qquad (2)$$

If the logarithm of each side of (1) is taken, the resulting expression is

$$\log y=\log K_1+n\log(E_0-E).$$

From the absorption data of Fig. 1B an end point E_0' is assumed. A plot on log-log paper is then made of y *vs.* $(E_0'-E)$ and the slope of the curve is determined to give a value of n, say n'. Using this value n' a plot on linear paper is made of $y^{1/n'}$ *vs.* E. From expression (2) it can be seen that when the ordinate is zero a value for the end point, say E_0'' can be obtained. Using this value E_0'' a new value n'' of the exponent is obtained. This new value of the exponent is then used to get a more accurate value for the maximum beta-energy. These approximations are repeated until a sufficiently accurate value is obtained.

In all determinations done here successive approximations to E_0 have formed a convergent series. If a graph is plotted of the change in E_0 assumed against the E_0 obtained, then an extrapolation to $\Delta E=0$ will give the end energy exactly.

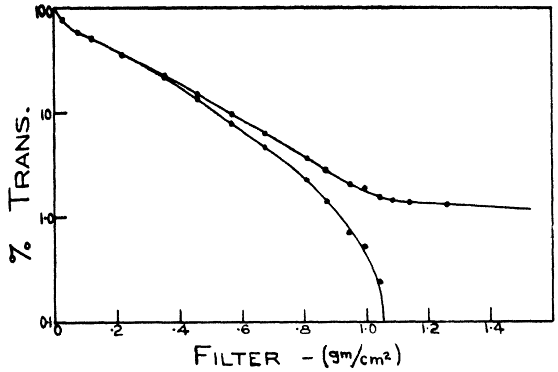

FIG. 2. Absorption curve for β-rays from Cu^{62}. Kink in curve at small filter thickness seems to indicate another component; this is being investigated.

Copper samples of 418 mg/cm² thickness were irradiated for 20 minutes at 70 R/min. in front of the University's 22-Mev betatron. An absorption curve was obtained and after corrections for loss of counts, the absorption curves were analyzed by this method as shown in Figs. 2, 3, and 4.

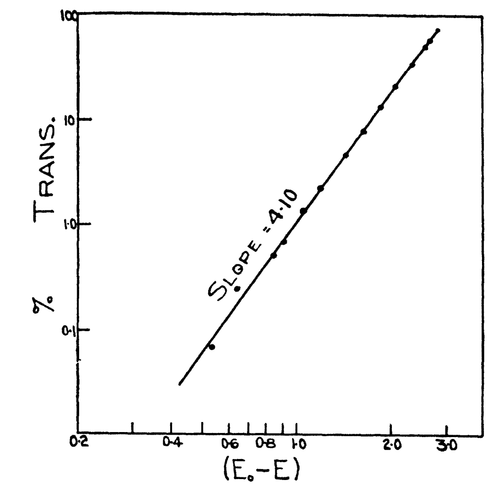

FIG. 3. Method of determining the value of n. The abscissas are the energies corresponding to given filter thicknesses as obtained from the range-energy curve.

Three separate determinations gave end points of 2.91, 2.94, and 2.92 Mev. The mean of these values is 2.92 Mev and the possible error was estimated to be ±0.06 Mev. This value is in

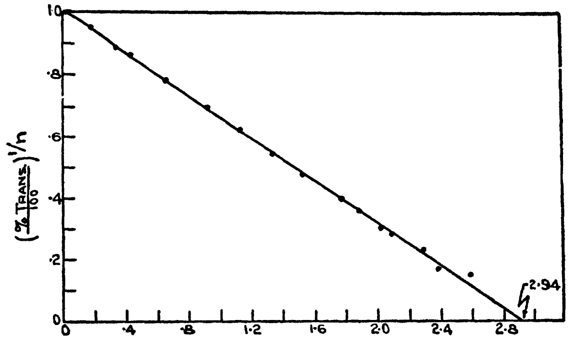

FIG. 4. Plot of $y^{1/n}$ against E to obtain E_0, the maximum β-energy.

essential agreement with a value reported by Becker and Kirn[6] who obtained as a "preliminary" value 2.80±0.05 Mev. This value was determined by spectrometric means.

In analyzing this data the range-energy curve for the absorption of electrons in aluminum as given in *The Science and Engineering of Nuclear Power*,[7] was used. All beta-spectra analyzed to date have indicated that this is the most reliable range-energy curve.

The above method of curve analysis may be used to obtain the end-energies of complex spectra. A paper is in preparation outlining the method in detail and giving further examples.

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Photo-Disintegration of Rhodium*

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ANGULAR and energy distributions of protons from nuclei disintegrated by collimated x-rays produced with a 20-Mev betatron have been studied, some preliminary results of rhodium disintegrations being presented here.

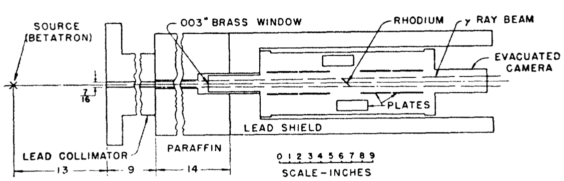

Fig. 1. Experimental arrangement, schematic.

A diagrammatic sketch of the apparatus is shown in Fig. 1. Alignment was checked optically and with x-ray shadowgraphs. Particles emitted from the target enter photographic emulsions (200μ Ilford) in an evacuated "camera." Only those tracks beginning at the surface are measured; neutron-proton recoil tracks originating in the body of the emulsion are sparse enough and evenly enough distributed so that they contribute negligibly to surface tracks, which are observed to have the correct directions for the protons to originate in the target. Energies are evaluated

Table I. Ratios of small-angle to right-angle intensities.

Proton energies, Mev	3.5–5.5	5.5–7.5	7.5–9.5	9.5–11.5
Ratios	0.69±0.14	0.75±0.10	0.54±0.10	0.23±0.08

by the usual range relationship[1] and are corrected for loss in the 0.025-mm target.

Figure 2 shows histograms of observed intensities I (=number of protons per hundredth steradian) for 3 plate positions, 20° (forward)±7°, 90°±12°, and −20° (=160°)±7°, the factor to convert I to N, the number of observed tracks, being stated on each histogram. Fore and aft intensities do not differ within present statistical errors, but right-angle emission predominates over emission at small angles, particularly at the higher proton energies. The small-angle intensity is averaged from the fore-and-aft positions and its ratio to right-angle intensity is shown in Table I.

Some such angular asymmetry might be expected from either of the dipole theories,[2,3] though the effect has yet to be estimated quantitatively, either with these or the compound-nucleus models.[4]

A similar irradiation with a heavy paraffin target served to check the betatron x-ray spectrum[5] which, with the theoretical deuteron cross sections,[6] is consistent with our observed proton spectrum. From the upper limit of the x-ray energies and the highest energy rhodium proton tracks on the 90° plate, a threshold of 8±1 Mev is obtained. By comparing intensities on the 90° plates from the two targets (monitoring the beam with an ion chamber), it is found that the rhodium γ-p cross section is 4.0±0.5 times the deuteron γ-p cross section for the 15–20-Mev gamma-energy range. Using the value from the symmetrical theory for the deuteron cross section[7] at 17.5 Mev and 90°, then, with the foregoing rhodium—deuteron ratio, the rhodium cross section for 17.5±1.0 Mev and 90° comes out to be $3.6(\pm 0.5)\times 10^{-28}$ cm²/sterad. With this value and with the observed angular distribution, the integral cross section for the same energy is $3.5(\pm 0.6)\times 10^{-27}$ cm². These cross sections apply to disintegration into a normal Ru^{102} nucleus; that excited states of the latter are not much involved in disintegrations by 15—20-Mev gamma-rays is

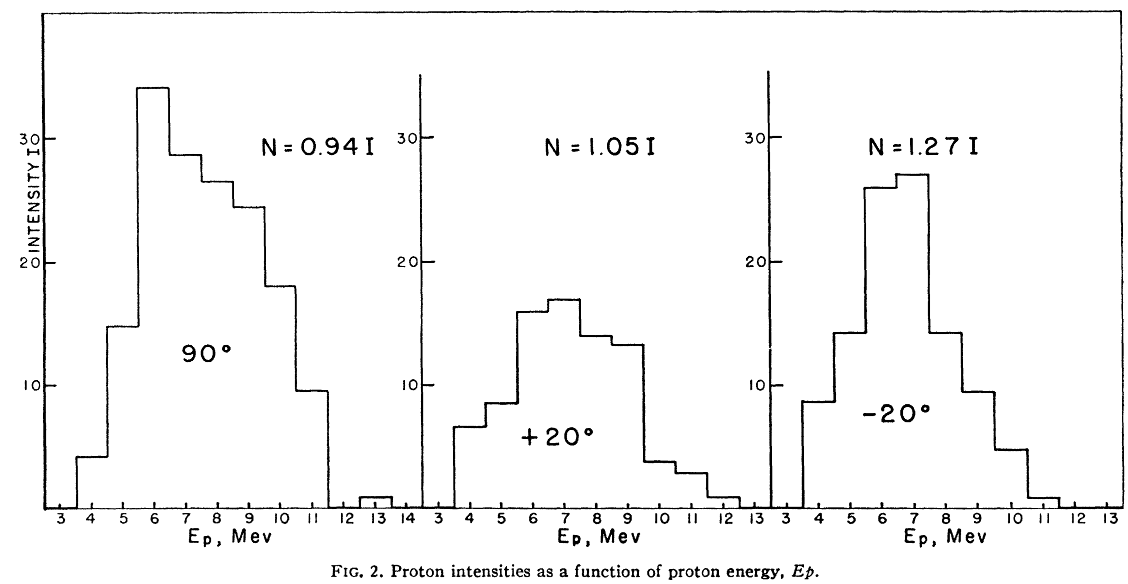

Fig. 2. Proton intensities as a function of proton energy, E_p.