TABLE I. Linear absorption coefficients in cm^{-1}.

Absorber	1.14 Mev	1.30 Mev
Iron	0.426 cm^{-1}	0.400 cm^{-1}
Copper	0.460	0.440
Lead	0.678	0.610

laboratory for many hours. With these very strong samples it was possible to make observations through much thicker layers of the absorber than had been done before and hence more accurately determine the absorption coefficients. These values together with the absorption coefficients for iron are collected in Table I.

The same values are shown graphically, along with the curves computed[2] by Heitler, in Fig. 1. There is some

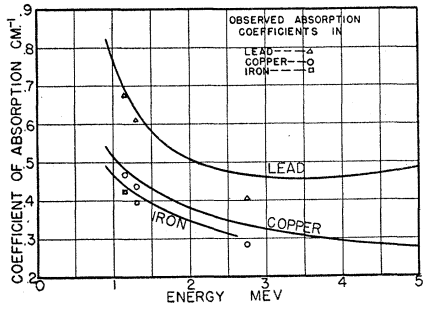

FIG. 1. Absorption coefficients, observed and computed (Heitler).

uncertainty in the energy of the cobalt radiation as it has been reported[3] to be complex, with energies 1.1 and 1.33 Mev. The value of the absorption coefficient recorded is that after passing through 9 cm of lead, and hence 1.3 Mev is used. The assumption of a lower value for the energy would have increased the observed discrepancy.

It is apparent that in every case the experimental points are below the computed Heitler curves, leading to a conclusion similar to that expressed in the previous paper, namely, an inadequacy in the Klein-Nishina formula at high energies.

[1] J. M. Cork and R. W. Pidd, Phys. Rev. **66**, 227 (1944).
[2] W. Heitler, *The Quantum Theory of Radiation* (Clarendon Press, Oxford, 1936).
[3] M. Deutsch and L. G. Elliott, Phys. Rev. **62**, 558 (1942); C. E. Mandeville and H. W. Fulbright, Phys. Rev. **64**, 265 (1943).

A New Method for Determining Thresholds in γ-n Processes

MARCELLUS L. WIEDENBECK AND C. J. MARHOEFER
Department of Physics, University of Notre Dame, Notre Dame, Indiana
October 20, 1944

AN exact determination of the threshold energy of photo-disintegration is of importance in nuclear physics and is especially useful in determining the relative masses of various nuclei. Up to this time, only two elements have been quantitatively studied in this connection, namely, beryllium and deuterium. However, it seems probable that many more will be studied in the near future, and a discussion of the methods previously used and of the new method developed in this laboratory thus seems justified.

The earliest method used[1] consisted in irradiating a sample of beryllium or deuterium with the γ-rays from natural sources, ThC″, etc., the energy of which is known, and observing the energy of the proton liberated from the process, ${}_1D^2+\gamma\rightarrow{}_1H^1+{}_0n^1$. The threshold energy was then the energy of the γ-ray minus twice the energy of the proton. The values obtained for the threshold determined in this manner vary from 2.16 to 2.26 Mev. More recent experiments indicate that the threshold for deuterium is 2.18 Mev and that of beryllium is 1.63 Mev.

With the introduction of various devices to produce high energy electrons, it became possible to vary easily the maximum energy of the x-rays and thus to study the cross section for disintegration as a function of the accelerating potential. In general, by this method the emitted neutrons were slowed down with paraffin and then detected by means of the activity produced in silver or rhodium. The activity obtained from such an arrangement is proportional to the total cross section for the process and when plotted against the accelerating voltage, all other quantities kept constant, gives a curve[2] of the form $A=K(V-V_t)^p$ where K and p are experimental constants and V_t is the threshold potential. Such a curve for deuterium is plotted in Fig. 1 (broken curve). The value of the threshold can be obtained by extrapolating this curve to zero activity.

The method described above has the disadvantage that the value chosen as the threshold depends only upon the few experimental points near the threshold where the activity is low. For a higher degree of accuracy, it is imperative that several points be obtained very close to the threshold.

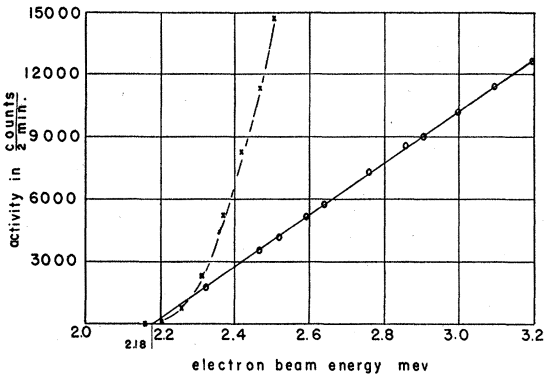

FIG. 1. Neutron counting rate *versus* accelerating potential. Broken curve, drawn from experimental points marked as crosses, obtained by interposing paraffin between deuterium samples and detector. Solid curve obtained without the use of paraffin.

The present method makes use of the resonance absorption of neutrons by rhodium or silver. It is well known, from theory[3] and from experiments on the excitation of nuclei by x-rays,[4,5] that the intensity of any isochromat in

the thick target continuous x-ray spectrum increases linearly with applied electron accelerating potential greater than the energy of the isochromat. Therefore, in a γ-

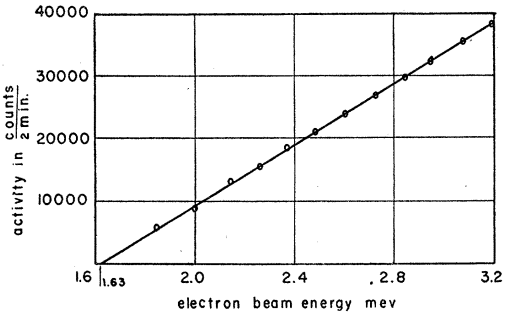

FIG. 2. Neutron counting rate *versus* accelerating potential for disintegration of beryllium. The curve was obtained without the use of paraffin.

n process, the number of neutrons of a given energy should also be linear with the applied voltage V, when

$$V \geq V_t + \frac{A}{A-1} V_n$$

(V_t being the threshold potential; A, the atomic weight of the nucleus being disintegrated; and V_n, the energy of the neutron being considered).

If no paraffin or other hydrogen-containing materials is present to slow down the emitted neutrons, the detector will be sensitive to essentially only one such neutron "line" of energy equal to the resonance energy of the detector and will not be affected by the faster neutrons. Thus the activity *vs.* accelerating potential curve should give a straight line intersecting the abscissa at the threshold potential.

This conclusion was tested with both deuterium and beryllium. The detector used was an argon-ether filled counter with a rhodium cathode. Small samples of deuterium and beryllium were bombarded for two minutes by the x-rays produced by a beam current of 100 microamperes striking a thick gold target. The activity was taken as the number of counts above background obtained during the two minutes after the irradiation was stopped.

The activity is plotted (solid curves in Fig. 1 and Fig. 2) from the threshold to 3.2 Mev as a function of the applied potential. It is seen that in both cases a straight line is obtained, which when extrapolated to zero activity, gives the threshold for the process, namely, 1.630 ± 0.006 for beryllium and 2.185 ± 0.006 for deuterium.

Thus, the threshold can be determined from a linear curve drawn through many points separated by very considerable distances. By this method the thresholds can be determined with a high degree of accuracy.

[1] J. Chadwich and M. Goldhaber, Proc. Roy. Soc. **151**, 479 (1935). N. Feather, Nature **136**, 468 (1935).
[2] F. E. Myers and L. C. Van Atta, Phys. Rev. **61**, 19 (1942).
[3] E. Guth, Phys. Rev. **59**, 325 (1941).
[4] B. Waldman and M. Wiedenbeck, Bull. Am. Phys. Soc. **17**, Nos. 4, 5 (1942).
[5] M. Wiedenbeck, Bull. Am. Phys. Soc. **19**, Nos. 3, 5 (1944).

Showers of Penetrating Particles

O. SALA AND G. WATAGHIN
Department of Physics, University of São Paulo, São Paulo, Brazil
November 24, 1944

COMPARATIVE studies of showers of penetrating particles at various altitudes with different materials were begun in July and August, 1944, in Campos de Jordão (Brasil) at an altitude of 1750 m and latitude 23°, and in São Paulo (altitude 750 m and latitude 23° 5′).

The multivibrator circuit,[1] elaborated by M. D. de Souza Santos, was adopted in connection with counters of fast type (alcohol-argon mixture). The resolving time of the coincidence set used was $\sim 6 \times 10^{-6}$ sec. The rate of chance 4-fold coincidences in all experiments was negligible. The efficiency was tested before and after the experiments and was >97 percent. The arrangements XV and XVI are indicated in Fig. 1. They are of the type used in previous experiments in order to observe showers of penetrating particles.[2]

Fourfold coincidences were observed between counters fully surrounded by lead of thicknesses not smaller than 10 cm Pb and separated also by 10 cm of lead.

In the experiment XVI the arrangement of counters and lead was the same as the experiment XV, and only an absorber of water was added. A total amount of about 750

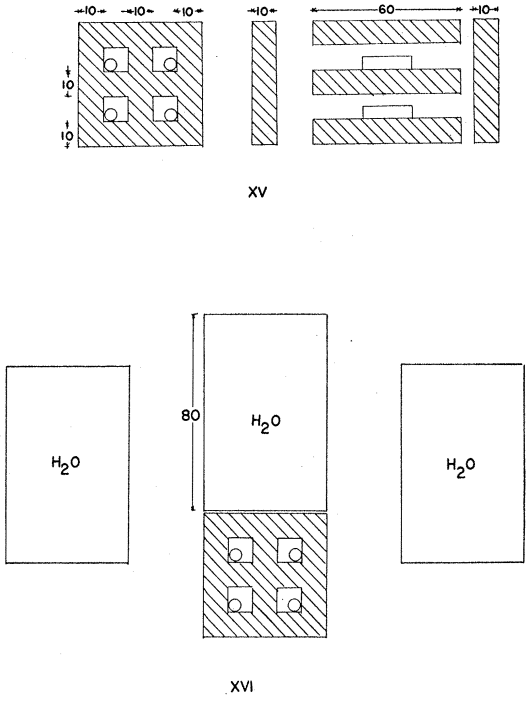

FIG. 1.

liters of water was used forming a layer of 80-cm thickness. The preliminary results are given in Table I.