Photodisintegration of Be^9 from Threshold to 5 Mev*

MARK J. JAKOBSON
Montana State University, Missoula, Montana
(Received February 21, 1961)

A bremsstrahlung-photon difference method measurement of the $Be^9(\gamma,n)$ cross section indicates maxima in the cross section of 1.15 ± 0.15, 0.55 ± 0.1, 1.2 ± 0.2, and 1.0 ± 0.3 mb at energies of 1.70, 2.40, 2.95, and 4.6 Mev, respectively. The angular distribution of the neutrons corresponding to the 1.70- and 4.6-Mev peaks is spherically symmetric; $d\sigma/d\Omega=a+b\sin^2\theta\,(a/b=1.0\pm0.2)$ for the 2.95-Mev peak.

THE photoneutron cross section of Be^9 has been measured by bombarding an inch thick Be target with the bremsstrahlung from monoenergetic electrons striking a tantalum target. Previously published measurements of $Be(\gamma,n)$ cross sections in this energy range have essentially been confined to energies below 2.76 Mev.[1–11]

The monoenergetic electrons ($\Delta p/p\sim0.5\%$) were obtained by sending electrons from a linear accelerator through an analyzer magnet which had been calibrated by means of the floating wire technique. The electrons then passed through a steering magnet to the target chamber. The steering magnet was necessary to provide an electron beam free from photons produced in the carbon slit system of the analyzer magnet. The target chamber was made an integral part of the accelerator vacuum system. For the photodisintegration, the electrons were stopped by the Be target, which was part of the collector cup. The neutron production without the tantalum target was subtracted from the neutron production with the tantalum target to obtain the bremsstrahlung contribution.

The neutrons were detected by a BF_3 long counter embedded in paraffin and shielded with a boric anhydride and paraffin shield. The insertion of 12 in. of lead between the target and the front of the counter reduced the counting rate by almost 90%. The counter was gated off during the electron pulse and for 50 μsec thereafter. The counter efficiency was determined by removing the Be target and inserting in its place a calibrated RaBe neutron source.

The excitation function for photoneutron production was measured with the counter at an angle of 90° with the incident photon beam. Measurements were made using 50-kev and 100-kev increments of electron energy. The differential cross section at this angle was calculated using the corrected Sauter-Fano[12] bremsstrahlung spectrum and a photon difference method.[13]

Initial measurements have been made of the angular distribution of the photoneutrons for angles 90° to 30° inclusive using 10° intervals. The cross section resulting from the combination of the differential cross section at 90° and the measured angular distribution is plotted in Fig. 1. The cross section rises rapidly from threshold to a maximum of 1.15 ± 0.15 mb at 1.70 Mev, has a minimum at 2.2 Mev, a slight peak at 2.40 Mev, rises again to a maximum of 1.2 ± 0.2 mb at 2.95 Mev, decreases to a broad minimum and increases again to a maximum of 1.0 ± 0.3 mb at 4.6 Mev and then slowly decreases. The errors stated are those associated with reproducibility. Previously published measurements are presented in Fig. 2 with this measurement plotted for comparison purposes.

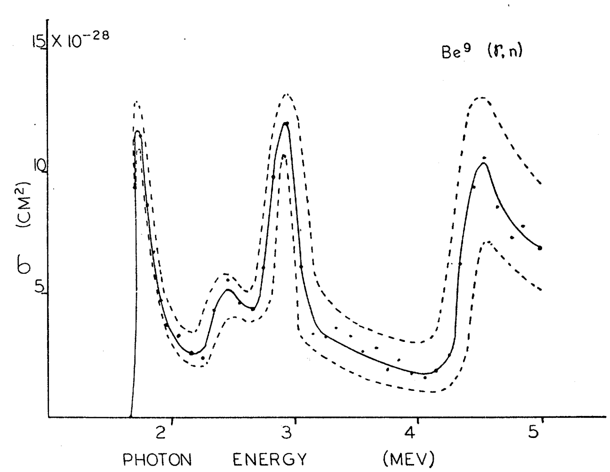

FIG. 1. Plot of the photoneutron cross section of Be^9 resulting from measurements described in this article. The errors indicated by the dashed lines represent standard deviations associated with reproducibility.

* This work has been supported by the National Science Foundation.

1 B. Russell, D. Sachs, A. Wattenberg, and R. Fields, Phys. Rev. **73**, 545 (1948).
2 A. H. Snell, E. C. Barker, and R. L. Sternberg, Phys. Rev. **80**, 637 (1950); A. H. Snell (unpublished). See reference 5.
3 E. Segrè (unpublished). See reference 5.
4 L. Elliott (unpublished). See reference 5.
5 B. Hamermesh and C. Kimball, Phys. Rev. **90**, 1063 (1953).
6 J. H. Gibbons, R. L. Macklin, J. B. Marion, and H. W. Schmitt, Phys. Rev. **114**, 319 (1959).
7 W. John, F. J. Lombard, E. T. Moore, and J. M. Prosser, Bull. Am. Phys. Soc. **5**, 44 (1960).
8 J. M. Prosser and W. John, UCRL-5996 (unpublished).
9 R. L. Walter, M. F. Shea, and W. C. Miller, Bull. Am. Phys. Soc. **5**, 229 (1960).
10 R. C. Mobely and R. A. Laubenstein, Phys. Rev. **80**, 309 (1950); J. C. Noyes, J. E. Van Hoomissen, W. C. Miller, and B. Waldman, Phys. Rev. **95**, 396 (1954).
11 M. Jakobson Bull. Am. Phys. Soc. **5**, 493 (1960). (Note the typographical error present in the abstract in that 13.0 ± 0.20 mb should have read 1.30 ± 0.20 mb.)
12 U. Fano, H. W. Koch, and J. W. Motz, Phys. Rev. **112**, 1679 (1958).
13 A. S. Penfold and J. E. Leiss, *Analysis of Photo Cross Sections* (University of Illinois Press, Urbana, Illinois, 1958).

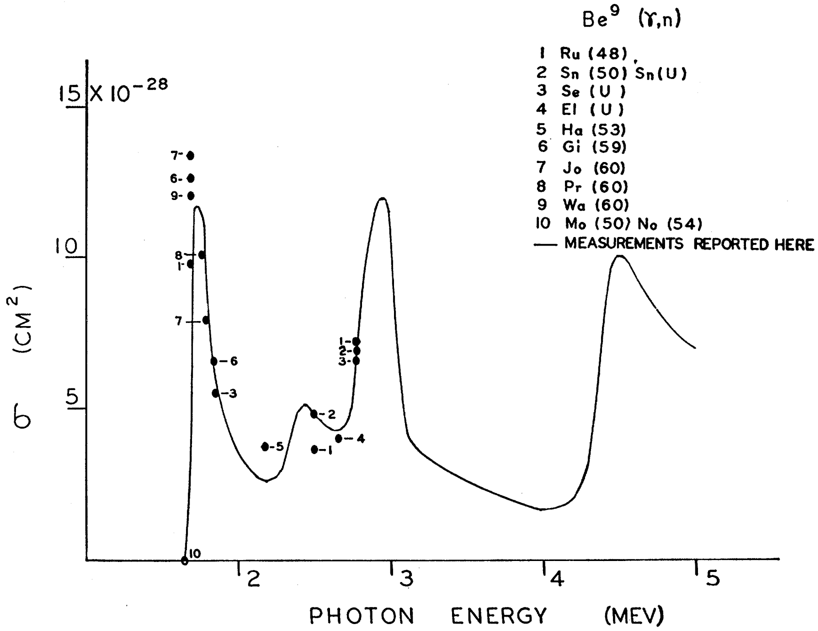

FIG. 2. Previously published measurements for the $Be^9(\gamma,n)$ cross section are indicated so that they can be compared with the results presented in Fig. 1.

The photoneutron angular distribution measurements indicate that neutrons corresponding to the 1.70-Mev peak have a spherically symmetrical distribution. The isotropic nature of this peak has been observed previously.[14] The neutrons produced by 2.40-Mev bremsstrahlung are not quite isotropic, with a slightly higher production at 90° with respect to the photon beam. The angular distribution of the neutrons corresponding to the 2.95-Mev peak can be fit with a curve of the form $d\sigma/d\Omega = a + b\sin^2\theta$, where $a/b = 1.0 \pm 0.2$. The neutrons from the increase in the cross section at 4.6 Mev have a spherically symmetric distribution. The angular distribution measurements are being continued.

The peak in the cross section just above threshold is in accord with previous measurements. The slight peak at 2.40 Mev is presumably a magnetic excitation of the well-known 2.43-Mev level. The peak at 2.95 Mev has an angular distribution compatable with an electric dipole transition to a *d* state. The increase in the cross section at 4.6 Mev, even though this measured increase has associated with it a rather large error, is difficult to explain as a ground-state transition since the emitted neutrons have a spherically symmetrical angular distribution.

It has been pointed out to the author by Blair[15] that a peak in the cross section at 4.6 Mev could be accounted for by assuming there is substantial coupling of the odd neutron to both the ground and first excited states of Be.[8] This would tend to reduce the photodisintegration cross section just above threshold. As a result the cross section computed by Francis, Goldman and Guth[16] for a diffuseness parameter of 0.6f would be in better agreement with experiment.[15]

[14] B. Hamermesh, M. Hamermesh, and A. Wattenberg, Phys. Rev. **76**, 611 (1949).

[15] J. S. Blair (private communication).

[16] N. C. Francis, D. T. Goldman, and E. Guth, Phys. Rev. **120**, 2175 (1960).