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PHOTO-EJECTION OF PROTONS

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C. Levinthal and A. Silverman

June 20, 1950

Berkeley, California

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PHOTO-EJECTION OF PROTONS

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A proportional counter telescope system has been used to measure the energy and angular distribution of protons ejected from various targets by the gamma-ray beam of the Berkeley synchrotron. The protons pass through two counters with 29 mg/cm^2 of aluminum between them. Discriminators are used on each channel so that only protons with a residual range of 30 mg/cm^2 of aluminum after leaving the rear counter are recorded. The energy lost in the rear counter by a proton of this energy is about twice the maximum possible loss of an electron, so that no single electron can be recorded. To minimize the effect of pile-up of electrons, the pulses from the proportional counter were clipped to about 0.4 μsec. by a shorted cable. Since the rise time of the pulses was about 0.3 μsec., very little pulse height was sacrificed by this method. The operation of the system was checked by pulse height measurements using a ten channel pulse height analyzer, by introducing artificial delays to check the accidental coincidences, and by noting that the counting rate was proportional to beam intensity. The measurements were made with the beam collimated to a one inch diameter. The counters were surrounded by about six inches of lead with a one inch entrance hole into the first counter. For most of the work, the counters were at six inches from the beam center. Data were obtained by varying the thickness of the absorber in front of the counter and by rotating the system about the target point.

Energy distributions from 8 - 70 Mev have been obtained at 90° to the beam direction using carbon, copper and lead targets. The results can be quite

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well represented by $N(E) = K/E^n$. $N(E)$ is the proton yield per Mev at energy E. K is a constant, different for each element but independent of energy; and $n = 1.7 \pm 0.1$ for carbon; 1.9 ± 0.1 for copper; and 2.2 ± 0.2 for lead. The lead distribution shows the expected decrease below the Coulomb barrier. The relative yields at 40 Mev with about 5 percent statistical errors are 6.0, 26.7, and 75.0 for carbon, copper, and lead respectively. Thus, for these three elements the cross sections are approximately proportional to the number of protons in the target nucleus.

The angular distributions of the protons from carbon and copper were measured at two different energies. Table I shows the results for proton energies between 8 - 12 Mev, and Table II for proton energies between 30 - 40 Mev. In all cases the yields are normalized to unity at 90°.

TABLE I

Relative yield of 8-12 Mev protons as a function of angle

Angle	Relative Yield	
	Copper	Carbon
45°	1.08 ± 0.09	1.13 ± 0.10
67°	1.09 ± 0.09	1.21 ± 0.12
90°	1	1
112°	0.95 ± 0.06	0.81 ± 0.10
135°	0.90 ± 0.07	0.82 ± 0.10

TABLE II

Relative yield of 30-40 Mev protons as a function of angle

Angle	Relative Yield	
	Copper	Carbon
45°	1.60 ± 0.18	1.58 ± 0.20
67°	1.28 ± 0.16	1.32 ± 0.15
90°	1	1
112°	0.80 ± 0.13	0.61 ± 0.12
135°	0.60 ± 0.10	0.51 ± 0.09

It is seen that the distribution is approximately spherically symmetric at the lower energy and has a pronounced forward peak at the higher energy.

There are at least two mechanisms that could give rise to the protons observed. One is the absorption of the gamma-ray by the nucleus with the subsequent "evaporation" of a proton from the excited nucleus and the other is the direct photoelectric ejection of a proton. The angular distribution in the 30-40 Mev interval indicates that the latter process plays an important part at this energy since it is difficult to see why the "evaporation" process should not be spherically symmetric. If one assumes a single particle model for the proton in the nucleus and some potential $v(r)$, the cross section as a function of energy may be calculated for the photoelectric process. Using the results of Bethe and Peierls[1] for the photodisintegration of the deuteron and a binding energy $\epsilon = 8$ Mev for the proton, one finds a rather good fit to the observed energy distribution for energies above 20 Mev. Below this energy, the observed cross section is higher than the calculated one. This can be understood by assuming that for energies below 20 Mev the protons arise primarily from an "evaporation" process and for energies

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[1] H. A. Bethe and R. Peierls, Proc. Roy. Soc. A <u>148</u>, 146 (1935)

above that primarily from a photo-effect.

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