Therefore we think there still exists no conclusive direct evidence about the nuclear interaction properties of fast pi-mesons, and that indirect evidence favors a large cross section.

[1] .O Piccioni, Phys. Rev. **77**, 6 (1950).
[2] Lovati, Mura, Salvini, and Tagliaferri, Phys. Rev. **77**, 284 (1950).
* Dr. Piccioni has kindly pointed out that the tray *D* has an apparent inefficiency of six percent, as judged by the difference between the rates A_2BC and A_2BCD; and that the *HS* defined only by A_2B contain on the average only one ionizing particle striking tray *C* in experiment III, when it contains only four counters. These facts modify the above statements only slightly. Still it appears that 2×12 or 24 percent of the stopped mesons are locally produced by neutrons, and likely an equal number are produced in secondary reactions by charged particles. The large statistical errors in experiment III make the precise magnitude of this effect very uncertain, but many cloud-chamber photographs (as well as recent, unpublished counter experiments) support the contention that the cascade multiplication of penetrating particles in hard showers is a process of major importance.
[3] H. S. Bridge and B. Rossi, Phys. Rev. **75**, 810 (1949).
[4] D. E. Hudson, Echo Lake Conference (June 1949).
[5] J. Tinlot and B. Gregory, Phys. Rev. **75**, 519 (1949). Their experimental arrangement was such as to measure a length intermediate between λ_a and λ_i.
[6] Bernardini, Cortini, and Manfredini, Phys. Rev. **74**, 845 and 1878 (1948); E. P. George and A. C. Jason, Proc. Phys. Soc. London **A62**, 243 (1949) and *Research* (Special Supplementary Volume, Colston Papers) (1949); Harding, Lattimore, Li, and Perkins, Nature **163**, 319 (1949).
[7] G. Cocconi, Phys. Rev. **75**, 1074 (1949) and **76**, 984 (1949); E. P. George and A. C. Jason (unpublished communication).
[8] λ_a(air) = 118, J. Tinlot, Phys. Rev. **74**, 1197 (1948); λ_i(carbon) = 90–100, G. Cocconi (reference 7); λ_i(carbon) = 85, W. D. Walker and K. Greisen (unpublished); λ_i(carbon) = 70, E. P. George and A. C. Jason, reference 7.

Cross Sections for the Photo-Disintegration of Nitrogen and Oxygen Nuclei by 100-Mev Betatron X-Rays*

E. R. GAERTTNER AND M. L. YEATER
Research Laboratory, General Electric Company, Schenectady, New York
January 16, 1950

NUCLEAR disintegrations caused by x-rays from the 100-Mev betatron have been investigated with a cloud chamber.[1] The disintegrations studied are those occuring in the filling gas of the cloud chamber; they are observed as single, double (flag), and multiple (star) tracks. The singles are nuclear recoils mostly from (γ,n) processes; according to our preliminary analysis most of the flags in nitrogen result from (γ,pn) reactions; the stars represent various modes of disintegration involving the emission of several charged particles and probably neutrons. Approximate values of the integrated cross sections have been obtained for the flags in air, and for singles, flags, and stars in nitrogen and oxygen, for a peak betatron energy of 100 Mev. The latter measurements give the total integrated photo-disintegration cross sections for nitrogen and oxygen.

The experimental procedure is as follows. X-rays from the General Electric 100-Mev betatron pass through an aperture in a lead shield, which defines a beam $\frac{1}{8}$ in.×$\frac{3}{4}$ in. in cross section, and enter the cloud chamber through a thin window. The data for air are taken with the x-ray intensity adjusted so that an average of one positron-electron pair in ten expansions is formed in the gas. The data for nitrogen[1] and oxygen are taken at a higher intensity, yielding an average of one nuclear disintegration in five expansions; the growth time of the tracks is shortened in this case to reduce the background caused by electron tracks.

The measurements with the air-filled chamber involve a simultaneous observation of flags and positron-electron pairs. This gives a ratio of the flag cross section to the pair cross section, when account is taken of the x-ray energy interval in which flags are produced. The mean x-ray energy for producing flags in nitrogen is about 30 Mev, according to our previous measurements.[2] The ratio of the flag cross section to the pair cross section is given by a total count of 27 flags and a count of 344 pairs with energy in the range 30±10 Mev.[3] Using the pair cross section suitably averaged over this energy interval, we find the integrated flag cross section to be 0.3 Mev-barn. The estimated error is ±20 percent, determined mostly by the number of events counted.

The flag cross sections for nitrogen and oxygen can be derived from the value for air if their relative cross sections are known.[4] A comparison of these cross sections has been made by counting the flags produced in oxygen and in nitrogen by strong x-ray beams monitored with a Victoreen r-meter. The oxygen cross section is 90 percent of the nitrogen cross section, according to a count of 185 flags in nitrogen and 166 in oxygen for equal r-meter readings. The integrated flag cross section for each is, therefore, approximately equal to the measured value for air.

The flag cross section for nitrogen has been measured in an independent way by comparing the number of flags observed in nitrogen with the number of x-ray quanta in the appropriate energy interval at 30 Mev. The latter number is obtained from the reading of a Victoreen r-meter by the use of a previous absolute calibration[5] of the number of quanta per Mev at 30 Mev per unit r-reading. In this way we obtain an integrated flag cross section of 0.36 Mev-barn, in satisfactory agreement with the value measured by our first method. This result is based on a count of 212 flags. The estimated error is ±40 percent, determined primarily by the probable error of the intensity calibration.

The (γ,n) cross sections for nitrogen and oxygen have been derived from the ratio of singles to flags, on the assumption that these reactions are produced by x-rays in the same energy interval. For nitrogen the (γ,n) cross section is 25 percent[1] of the flag cross section, or 0.08 Mev-barn. For oxygen the (γ,n) cross section is 52 percent of the flag cross section, or 0.15 Mev-barn, based on a count of 315 flags and 164 singles.

The total photo-disintegration cross sections can be derived from the single and flag cross sections and our data relating to multiple disintegrations. The ratio of flags to stars is 3.0 for nitrogen;[1] for oxygen it is 4.4, as given by a count of 636 flags and 144 stars. Assuming the x-ray spectrum to be of the form dE/E and taking the energy range for star production to be about 30–60 Mev, we find the star cross section to be 0.16 Mev-barn for nitrogen and 0.11 Mev-barn for oxygen. The total integrated photo-disintegration cross section, up to 100 Mev, is therefore about 0.6 Mev-barn for both nitrogen and oxygen.

Our results for the (γ,n) cross sections are in good agreement with other measurements made in this Laboratory. Perlman and Friedlander[6] give values of 2.2 and 2.3, respectively, for the (γ,n) cross sections in oxygen and in carbon relative to nitrogen. Using the value of 0.15 Mev-barn for carbon measured by Lawson and Perlman,[7] one obtains a (γ,n) cross section of 0.14 Mev-barn for oxygen and 0.07 Mev-barn for nitrogen.

The cooperation of the betatron staff is gratefully acknowledged.

* The cloud-chamber equipment used in this investigation was developed under Contract N7onr 332 with the ONR.
[1] For additional information about the photo-disintegration of nitrogen see E. R. Gaerttner and M. L. Yeater, Phys. Rev. **77**, 570 (1950). The apparatus is described in Rev. Sci. Inst. **20**, 588 (1949).
[2] The energy dependence of flags and stars in nitrogen is discussed in reference 1. The same energy dependence is assumed for oxygen.
[3] The numerical value of the flag cross section is not sensitive to the choice of interval up to about ±20 Mev.
[4] About 1 percent argon is present in the air. A preliminary study of the flags produced in an argon-filled cloud chamber indicates that the effect of this contaminant is negligible.
[5] E. R. Gaerttner and M. L. Yeater, Phys. Rev. **76**, 363 (1949).
[6] M. L. Perlman and G. Friedlander, Phys. Rev. **74**, 442 (1948).
[7] J. L. Lawson and M. L. Perlman, Phys. Rev. **74**, 1190 (1948).

The Half-Life of Carbon Fourteen and a Comparison of Gas Phase Counter Methods*

WARREN W. MILLER, ROBERT BALLENTINE, WILLIAM BERNSTEIN, LEWIS FRIEDMAN, A. O. NIER, AND R. D. EVANS
Brookhaven National Laboratory, Upton, New York, University of Minnesota, Minneapolis, Minnesota, and Massachusetts Institute of Technology, Cambridge, Massachusetts
January 16, 1950

OF the published determinations of the half-life of C^{14}, three have been done by methods that would allow accuracy of 5 percent or better. All are by mass spectrometry of a rich sample of active material and absolute gas counting of a diluted aliquot of the same material. The first[1,2] was done by diluting as carbonate ion in solution, and counting in a differential CO_2-CS_2 G-M counter which eliminates end effects. The value found for the half-life was 6360±200 years. Two more recent papers[3,4] have