cross sections of 0.40±0.03 barn for C^{12}, 0.37±0.03 barn for C^{13}. Table I shows the number of emergent prongs from the stars.

TABLE I. Number of emergent prongs from the stars.

Prongs	2	3	4	5	6	7	Total
C^{12}	23	49	24	3	2	1	102
C^{13}	32	44	30	2	0	0	108

Two-prong stars are included only when they could not have been elastic.

A feature of the stars is the high percentage of alphas emerging. Of protons emerging from carbon stars, the longest track lying wholly in the emulsion was 1046 microns, corresponding to an energy of 14.2 Mev. No "hammer tracks" from Li^8 have as yet been observed.

The mosaic of Fig. 1 shows a C^{12} ion stopped in Ilford 100μ E−1 emulsion without a nuclear reaction and one which entered another nucleus, with seven emergent prongs. The C^{12} ion had traveled 63 microns when it entered the target nucleus and accordingly had about 90-Mev kinetic energy remaining. The seventh prong is hidden in the main mosaic, since it is short and goes downward. Its presence is shown by the three pictures at the upper right, taken at increasing depths.

The interest and encouragement of Professors Ernest O. Lawrence, J. G. Hamilton, and E. M. McMillan are acknowledged with gratitude. The writer is particularly indebted to the operations staff of the 60-inch cyclotron under Mr. T. M. Putnam, Jr., and Mr. G. B. Rossi. Much painstaking work has been done by Mr. A. Oliver of the nuclear emulsion group of the Radiation Laboratory in preparing mosaics of nuclear events from carbon ions, of which those reproduced here are part.

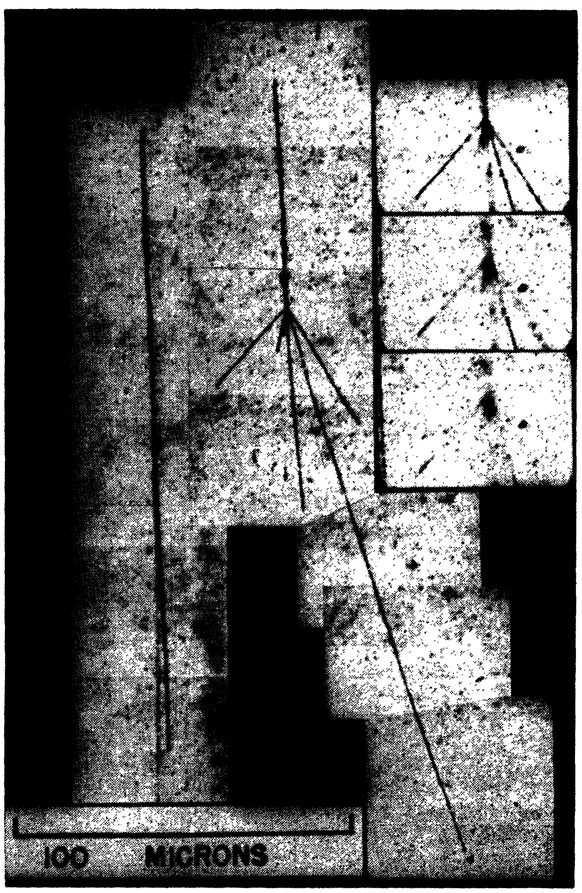

FIG. 1. C^{12} ion tracks in Ilford E-1 emulsion. One stopped without nuclear event; the other produced a seven-pronged star.

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The Photodisintegration Cross Section of the Deuteron

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(Received July 30, 1951)

THE photodisintegration cross section of deuterium by gamma-rays of ThC″ has been observed by measuring the difference between the total gamma-ray absorption cross sections in D_2O and H_2O. Although the difference is very small (approximately 0.3 percent), the effect can be magnified in a balance-type experiment by observing the difference in counting rates through many mean free paths of absorber. The ratio of the counting rates through two-dimensionally identical absorbers of D_2O and H_2O was observed for the sources Co^{60} and ThC″. The photodisintegration cross section obtained for 2.62-Mev gamma-rays of the ThC″ was (1.47±0.22) millibarns, which agrees within the statistical accuracy with the excellent measurements by Bishop *et al.*[1]

The sources were 300 mC of ThC″ and 3 curies of Co^{60}, respectively. The initial columnation in lead was (6.1×10^{-5}) solid angle subtended at the source by the beginning of the absorber. The absorbers were aluminum tubes 187 cm long, $1\frac{3}{4}''$ o.d.$\times1\frac{5}{8}''$ i.d., filled with distilled water and 99.88 percent D_2O.[2] The The detector was a scintillation counter with stacked 4-cm diameter NaI crystals totaling 9 cm long and a 5819 photomultiplier. A large amount of lead shielding was used around the detector to reduce background. The electronic bias setting was such as to count the upper 50 percent of the Co^{60} spectrum and the upper 30 percent of the ThC″ spectrum. The absorption coefficient of copper for the 2.62-Mev gamma-ray of ThC″ was determined using the same setup, and this agreed to within 0.2 percent with accurate absorption measurements made previously with different apparatus and setup.[3] This could be used to determine an extrapolated zero absorber counting rate, which, in conjunction with the water absorbers, gave a water cross section that agreed to within 0.2 percent with the measurements in reference 3. This is sufficient evidence to say that the amount of scattered radiation detected was negligible.

The ratio of the counting rates through D_2O and H_2O absorbers was determined by alternating absorbers and then counting to 1.5 percent statistical accuracy in each trial. One hundred determinations of the ratio were made for both sources. The energy of the Co^{60} gamma-rays are below the photodisintegration threshold and so give a ratio of counting rates determined by the ratio of molar volume of D_2O to H_2O, or in particular give the ratio of electronic gamma-ray cross section for the two tubes. The ratio of molar volumes so determined agreed within the experimental error with density determined values.[4] The ThC″ gamma-rays should give rise to the same electronic cross-section ratio and in addition include the photodisintegration cross section. The ratio of counting rates of D_2O/H_2O for the Co^{60} source was (1.0361 ±0.0020) in 11.85 mean free paths. The ratio for ThC″ was (1.0060±0.0023) in 7.96 mean free paths. This results in a difference of (0.0183±0.0027) in the counting rate due to D_2 in 187.1 cm of D_2O at 22°C. This gives a photodisintegration cross section of (1.47±0.22) millibarns per deuterium nucleus.

I am grateful for the encouragement of Dr. R. R. Wilson throughout the course of this experiment.

* This work was supported by the ONR.
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[2] The D_2O was furnished by The Stuart Oxygen Company, San Francisco, California.
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[4] E. Swift, Jr., J. Am. Chem. Soc. 61, 198 (1939).

Erratum: Quantum Statistics of Fields

[Phys. Rev. 83, 125 (1951)]
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THE following changes should be made in the article with the above title:

Equations (2.5) and (2.11): The factor T should be omitted.

Equation (3.13) should read:

$$S/V=-(2\pi)^{-3}k\int_0^\infty \log\{1-\exp(-\hbar^2K^2/2mkT)\}4\pi K^2dK+\frac{1}{(2\pi)^3}\frac{1}{T}\int_0^\infty\frac{\hbar^2K^2}{2m\{\exp(\hbar^2K^2/2mkT)-1\}}4\pi K^2dK.$$

Equation (4.14): add the factor mc^2.

Cosmic-Ray Star Production in Argon at Sea Level*†

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THE sea level rate of cosmic-ray star production in argon has been measured by direct observation of the N-ray nuclear interactions in the gas of an ionization chamber contained in a cloud chamber. The ionization chamber, a $3\frac{3}{4}$ in. diameter and $\frac{1}{16}$-in. walled brass cylinder 8 in. in length, open at both ends, and having a $\frac{1}{16}$-in. steel central wire, is mounted coaxially with the cloud chamber which has a useful rectangular volume 10 in.×10 in. ×8 in. depth[1] (Fig. 1). The gas, argon at 75 lb-in.$^{-2}$ absolute pressure saturated with iso-amyl alcohol, is common to both the cloud chamber and ionization chamber. A burst occurring in the ionization chamber generates a pulse which is used to trigger the expansion mechanism. Rapid reduction of the cylinder voltage from minus 1400 volts to ground, after electron collection is over, prohibits any appreciable motion of the positive ions and thus permits observation of the tracks of the burst producing particles. The regions exterior and interior to the ionization chamber are illuminated with Amglo flashlamps and photographed stereoscopically. A photographed array of neon bulbs indicates which of the counters (each 1 in.×16 in. effective area) above the chamber are discharged in coincidence with a burst. The chamber was operated under a light roof in an insulated box and maintained within a few degrees of 37°C. Only those bursts releasing more than 7 Mev (1.3 Po-alpha) were permitted to trigger the chamber. Oscillograph traces of the ionization chamber pulses were photographed.

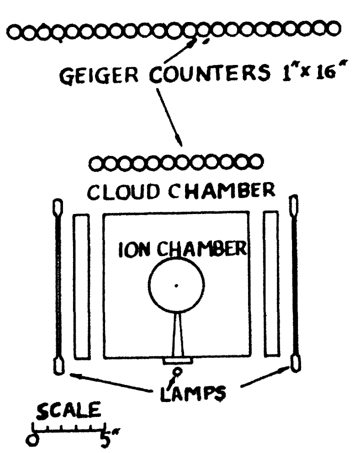

Fig. 1. Arrangement of ionization chamber, cloud chamber, and counters.

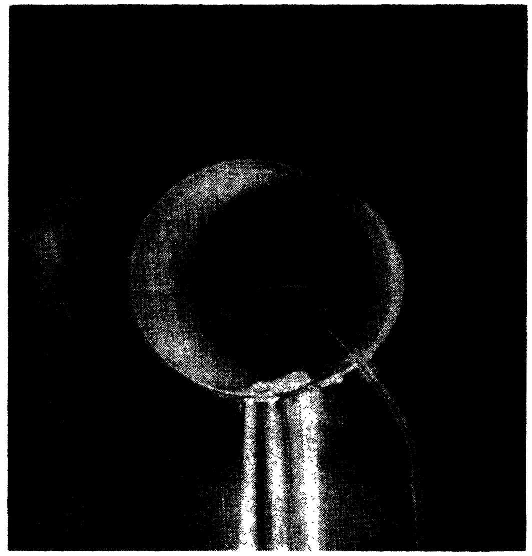

Fig. 2. A neutral particle interacts with an argon nucleus to produce a star in which 11 emitted ionizing particles are visible in the original negative. Protruding through the wall at the lower right is a wire carrying a Po-alpha calibrating source.

Bursts were produced by stars occurring in the wall and gas (see Fig. 2) of the ionization chamber and by electronic showers. In Table I the numbers of the above ionizing phenomena causing bursts in 365 hours of sensitive operating time are given. A plot of the spacial distribution of the origins of the stars occurring in the gas indicated that those occurring near the wall and the ends of the ionization chamber had less chance of being detected than those occurring nearer the axis and center of the chamber. In a centrally located cylindrical volume 7.16 cm in diameter and 12.2 cm long, where the wall and end effects are negligible, 37 stars of 1 or more prongs occurred in the gas in the sensitive time interval. Of these 27 were of three or more prongs. Since the photographs of the oscillograph traces of the bursts indicated the ionization chamber was working properly during this interval, the few instances in which blank pictures of the cloud chamber were obtained were attributed to inefficiency in the cloud chamber operation. The rate of star production in argon, after correcting

Table I. Number of ionizing phenomena causing bursts.

Sensitive time, hr	Stars in brass wall of 1 or more prongs	Stars in argon: 1 or more prongs	Stars in argon: 3 or more prongs	Bursts due to electronic showers
365	135	46	33	14