since the fluorescence yield differs only slightly for elements with $\Delta Z=1$ and the intensity ratio of the K electrons from Xe^{133} and Cs^{133} is 1:32, the obtained value can be considered as the fluorescence yield of Cs. Our value 0.89 ± 0.08 is higher than that obtained by Auger[11] in Xe (0.71) but is in good agreement with the value 0.91 from the semi-empirical curve given by Haas[12] from the theory of Wentzel.[13] The ratio of the intensities of the A_1 and A_2 lines 0.48, gives the probability ratio for ejection of an Auger electron from the L shell and from the M, N, $\cdots$shells.

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Scattering of 3.27-Mev Neutrons by Deuterons in the Wilson Chamber

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THE scattering of neutrons by deuterons is known to give a clue regarding the nature of the force between two nucleons, even at relatively small neutron energies.[1] The two main angular distribution measurements in this field with neutrons of 2.6 Mev from a (d, d) reaction, are those of Coon and Barschall[2] with 12,000 deuteron recoils in an ionization chamber, and of Darby and Swan[3] with 1500 deuteron tracks in a cloud chamber. However, as Darby and Swan maintain, their angular distribution data agree very closely with the "ordinary force" curve of Massey and Buckingham,[4] whereas Massey and Buckingham[4] point out that the data of Coon and Barschall fit better with their "exchange force" curve.

We investigated the angular distribution of neutrons scattered by deuterons with 3.27-Mev (d, d) neutrons in the cloud chamber. To eliminate the disturbing effects of the neutrons scattered into the chamber from the surrounding material and to account for corrections due to the geometry of the apparatus, the angular distribution of neutron-proton scattering was also investigated with the same neutron source and under the same geometrical conditions. Assuming that the (n, p) distribution is isotropic, one obtains a correction factor for the disturbing effects which is just the deviation from isotropy of the measured distribution. In two separate runs of photographs under different geometrical conditions 5000 proton recoils and 10,000 deuteron recoils were investigated. The two independently measured (n, d) angular distributions were found to agree well within the limits of statistical fluctuation. In Fig. 1 the angular distribution data for protons and deuterons in the second run of photographs (2800 proton recoils and 8200 deuteron recoils) are plotted in the center-of-mass system. Our data agree with those of Coon and Barschall.

In a recent theoretical work on the elastic scattering of neutrons by deuterons at 20 Mev, Verde[5] points out that a pronounced maximum occurring only at 180° is a characteristic feature of the "exchange force" theory and is also produced at smaller energies. This is in disagreement with the results of Buckingham and Massey[1] who find for neutrons of 11.5 Mev a pronounced maximum only at 0° for exchange as well as for ordinary force theories. Coon and Taschek,[6] who have extrapolated their data to a pronounced maximum at 0° from measurements made at 20° and above, point out that their angular distribution data at 14 Mev fit better with the "exchange force" curve of Buckingham and

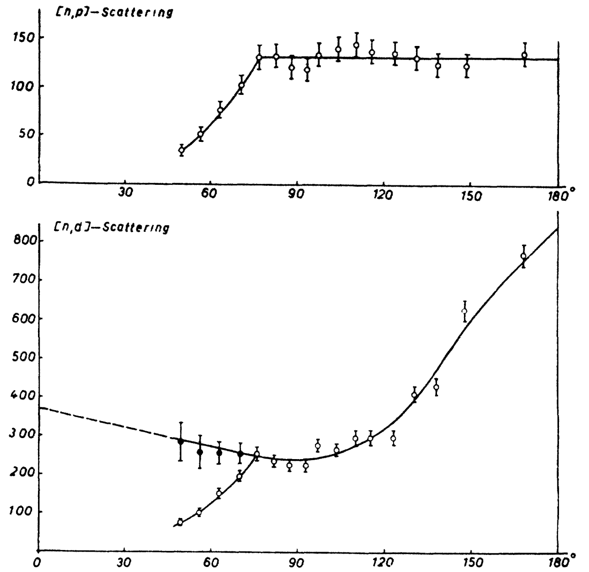

FIG. 1. Intensity of scattered neutrons *versus* angle of scattering in center-of-mass system. The empty circles represent the measured intensities; the full circles represent the corrected intensities, considering the isotropy of the (n, p) angular distribution. The dashed part of the curve is an extrapolation drawn to give a total number of recoils corresponding to the experimental total scattering cross-section values for the two processes.

Massey[1] at 11.5 Mev. On the other hand, this shape disagrees, according to Verde, with the "characteristic feature" of the "exchange force" theory, and fits qualitatively with the "ordinary force" curve of Verde at 20 Mev. If the data of the present experiment are compared with the curves of Massey and Buckingham[4] at 2.53 Mev, they fit much better with the "exchange-" than with the "ordinary-force" curve.

We wish to thank Dr. M. Verde for very interesting and useful theoretical discussions, also Dr. W. Zünti for help in carrying out the radiation with the neutron generator.

The detailed experiment will be published in *Helvetica Physica Acta*.

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Note on Angular Asymmetries in (γ, n) Reactions*

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THE (n, p) threshold reaction in aluminum has been used to detect photo-neutrons emitted from bismuth, lead, and tungsten targets irradiated with x-rays produced by the 20-Mev betatron at the Picatinny Arsenal. Emission of photo-neutrons was found to be more prevalent at right angles to the x-ray beam than in the direction of the beam. This asymmetry for fast neutrons [the (n, p) reaction in aluminum has a threshold of 4.6 Mev for a probability[1] of barrier penetration by the emitted proton of $\frac{1}{2}$] is in contrast to the symmetrical distributions found for lead and iron by Price and Kerst[2] who used a detector responding to slow neutrons as well.

The detector consisted of a stack of aluminum plates[3] enclosed in $\frac{1}{32}''$ cadmium. Their activity was measured with a thin-walled cylindrical Geiger counter following the end of a 10-min. irradiation. A decay curve was plotted in each case. With the exception of the first few minutes, during which an activity attributed to

2.3-min. Al^{28} was noticeable, the points could be fitted to a 9.6-min. half-life which has been established for the Mg^{27} end product of the aluminum (n, p) reaction.[4]

Targets were $\frac{3}{4}''$ diameter cylinders, 3″ long, the tungsten being in the form of the metal powder while the lead and bismuth were solid cylinders. The x-ray beam was perpendicular to the axis of the cylinder. During an irradiation, the betatron intensity as indicated by a monitor ionization chamber was kept constant to about 10 percent. Partial corrections for fluctuations in intensity were made by normalizing each initial activity to the same total number of roentgens.

The background of fast neutrons generated by the betatron made it necessary to sacrifice resolution by placing the detector adjacent to the target. Measurements were made at 0° and at both 90° positions with respect to the beam. A carbon target was used to take into account the background. The threshold of the detector together with the high (γ, n) threshold for carbon would prevent photo-neutrons from being detected in this case. The resultant activities, about the same for each position, are attributed to neutrons in the x-ray beam being scattered by the target or reaching the detector directly. Since the carbon target scatters neutrons to roughly the same extent as do the other target matrials used, these activities were just subtracted from the others to obtain the net photo-neutron effect. The results of at least two independent sets of measurements on each element are in the range

$$N_{90°}/N_{0°} = 2.0 \pm 0.5.$$

Within the limits of error, no significant differences for the different targets were noticed.

An angular dependence of the form $A + B\sin^2\theta$ would be expected if photo-disintegrations are principally due to dipole transitions. Because of the continuous nature of both the x-ray spectrum and the energy sensitivity of the detector, as well as the poor resolution, the experimental ratio is difficult to compare directly with theory, but is in qualitative agreement with considerations based on a shell structure model of nuclei.[5] If an average cross section of 0.025 barn for the aluminum (n, p) reaction is assumed, then comparing the results of these measurements with those of Price and Kerst on total neutron yields,[2] it appears that of the order of 1/10 of the total photo-neutrons from lead or bismuth are fast enough to activate the aluminum detector.

Acknowledgment is due Dr. E. O. Salant, who suggested this problem, and Dr. E. D. Courant for helpful discussions. I am also indebted to the officers and men of Picatinny Arsenal, in particular, to Mr. L. P. Goldberg and Dr. B. A. Lloyd, for enabling us to use the betatron and for rendering valuable assistance throughout.

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A Large Fluctuation in the Rate of Production of Nuclear Disintegrations Following a Solar Flare*

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In the course of a series of balloon flights in the stratosphere for the purpose of measuring the nuclear disintegration intensity in photographic emulsions as a function of altitude, one flight gave a very much larger intensity than normal. This flight was launched from Camp Ripley, Minnesota (56°N geomagnetic latitude) on May 11, 1949 and remained in the air from 18:48 to 22:30 Universal Time and reached a maximum altitude of 95,000 ft. This was about 23 hr. following the occurrence of the large solar flare[1] of May 10, 1949.

The intensity measurement of the production of nuclear disintegrations in photographic emulsions was referred to an altitude of 95,000 ft.; corrections having been made for the time of ascent and descent. These corrections were made possible since recent data to be published soon give a more detailed altitude variation[2] of stars of a specific number of prongs. The active volume of the emulsion examined for the determination of the frequency of stars was measured after processing it. The change in the volume due to shrinkage was determined from a number of sample plates selected at random from the plates used in the experiment. One-half of each plate was processed along with the others in the experiment, the other half was left unprocessed. Measurements of mass, area, and thickness of emulsion were made on both halves of the plates and compared with each other.

The intensity for the production of nuclear disintegrations during the flight of May 11 is compared in Fig. 1 with that during

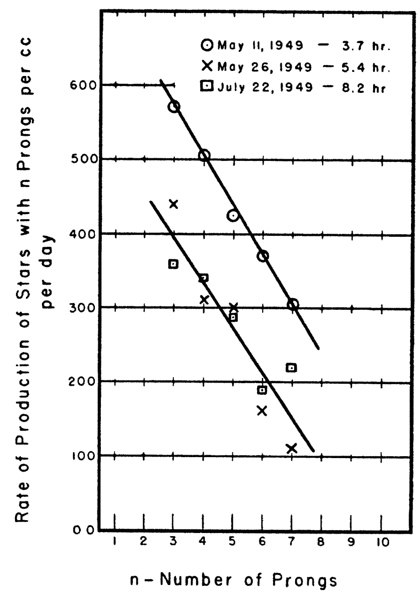

Fig. 1.

two other flights reaching the same altitude. During the flight of May 11, the intensity of production of stars having 3 to 8 prongs was 50±13 percent greater than the normal value. The intensity of heavy nuclei having atomic numbers greater than approximately 10 was within statistical error the same as that for a normal flight during the day.

The flare of May 10, 1949 began at 20:00–20:03 UT as repoted by Shapley and Davis[1] and was rated 3^+ by observers at the McMath-Hulbert observatory.[3] Following the solar flare, a magnetic storm commenced at 06:24 UT on May 12, 1949. Observations by Forbush[4] at Cheltenham, Maryland (72 meters elevation) and Huanacayo, Peru (3350 meters elevation) with shielded ionization chambers showed no measurable change in the cosmic-ray intensity during the period from the start of the flare to the occurrence of the magnetic storm; however, a decrease of a few percent was observed during the magnetic storm.

Only four significant increases of cosmic-ray intensity have been observed in the past 13 yr. and all seem to have been closely associated with solar flares.[3,5] The unusually large latitude dependence of these increases indicates that they must be due predominantly