LOSS OF C^{11} FROM PLASTIC FOILS AND ITS EFFECT ON CROSS-SECTION MEASUREMENTS*

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In the course of measurements of the ratio of the cross sections for the $C^{12}(p, pn)C^{11}$ and $Al^{27}(p, 3pn)Na^{24}$ reactions using stacked polyethylene and aluminum foils, it was discovered that up to 15% of the C^{11} activity may be lost by the plastic foils during irradiation. We ascribe the observed results to hot atom reactions of the recoiling C^{11} atoms leading to gaseous products which diffuse out of the target. This phenomenon seriously affects the use of the C^{11} production rate in thin plastic foils to monitor high-energy proton beams.

Our observations to date may be summarized as follows:

1. Production rate relative to 95-mg/cm² plastic scintillator. We have bombarded stacks of polyethylene, "oriented" polystyrene, graphite, and 95-mg/cm² polystyrene plastic scintillator in the external 3-Bev proton beam of the Cosmotron and have observed that the apparent production rate of C^{11} per (gram/cm²) of carbon varied significantly with both the thickness and chemical composition of the target material. The target diameter was sufficiently large to intercept most of the beam so as to reduce the effects of misalignment of the foils. The target stacks were relatively thin (<0.5 g/cm)² to minimize production of secondary particles and the foils were sandwiched in such a manner as to compensate for nuclear recoil losses. The results of these measurements are shown in Fig. 1. It appears that the loss from polystyrene is less than from polyethylene of equal thickness. However, one should not assume that other batches of these materials will behave precisely the same. It was also observed that the apparent loss of C^{11} activity from 9.5-mg/cm² polyethylene was the same for foils irradiated in vacuum as in air.

2. Observation of C^{11} activity in the gas phase. Foils were irradiated in an aluminum tank containing 1 atmosphere of helium. After irradiation, the gas was expanded into a proportional counter. In one experiment the tank contained two 95-mg/cm² plastic scintillators. The C^{11} in the gas phase corresponded to a loss of (0.8 ± 0.1)% of the activity produced in the scintillators. A similar experiment with no plastic in the tank gave a blank of ~5% of the above value. The data in Fig. 1 have been normalized to this value.

Polystyrene foils, 7.7 mg/cm² thick, produced a C^{11} activity in the gas phase equivalent to a loss of (1.7 ± 0.2)%. One irradiation of 9.5-mg/cm² polyethylene foils with cyclotron neutrons (20-Mev H^2 + Be) to produce C^{11} by the $(n, 2n)$ reaction gave a gaseous activity corresponding to a loss from the foils of (8 ± 1)%. The activity of the foils measured relative to a 95-mg/cm² scintillator indicated a loss of (12 ± 2)%. The accuracy of the present experiments does not indicate whether or not all of the activity lost from the foils is retained in the gas phase.

3. Irradiation at low temperature. The 9.5-mg/cm² polyethylene foils were irradiated in sealed polyethylene envelopes at liquid nitrogen temperatures. A half hour after irradiation it was observed that, when a foil was warmed to room temperature, (9 ± 1)% of the activity was lost with a half-time of ≤2 min. If the foil was warmed in a sealed vial, no loss of activity was

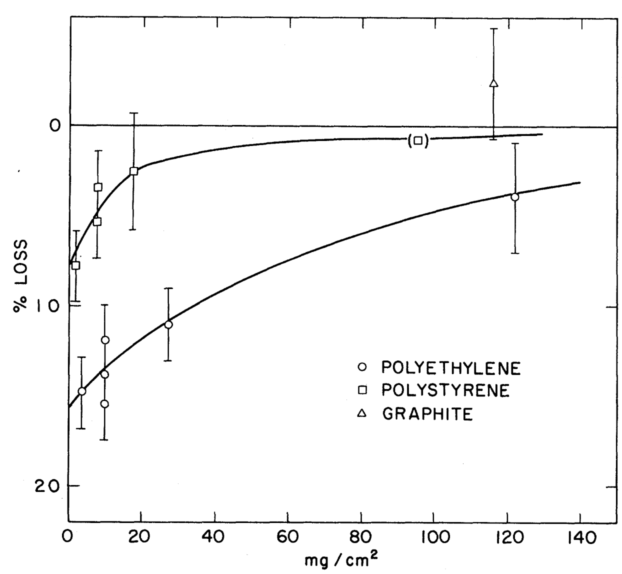

FIG. 1. The percent loss of C^{11} from various target materials as a function of the thickness of the material. The measurements were made relative to a 95-mg/cm² plastic scintillator and normalized to a loss of 0.8% for this point. The normalized point is indicated by parentheses in the figure.

observed until the vial was opened.

4. Composition of the radioactive gas. Gas chromatography with charcoal and silica gel columns was used to analyze[1] the chemical composition of the radioactive gas liberated from 9.5-mg/cm^2 polyethylene. The composition was found to be 57% methane, 36% acetylene, 6% ethylene, and 1% ethane. No CO or CO_2 was observed.

Absolute measurements of the $C^{12}(p, pn)C^{11}$ cross section may have been affected by the loss of C^{11} in those cases where thin plastic targets were used. Recent measurements in the Bev region[2,3] have used polystyrene targets sufficiently thick so that the correction is less than 1%. The loss effect may also account for some of the discrepancies in the $C^{12}(p, pn)C^{11}/Al^{27}(p, 3pn)Na^{24}$ cross-section ratios which have been reported.

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[1]See J. Yang and A. P. Wolf, J. Am. Chem. Soc. 82, 4488 (1960).

[2]J. B. Cumming, G. Friedlander, and C. Swartz, Phys. Rev. 111, 1368 (1958).

[3]N. Horowitz and J. J. Murray, Phys. Rev. 117, 1361 (1960).

EXTREMELY ENERGETIC COSMIC-RAY EVENT*

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This note is a preliminary report on an extremely large cosmic-ray air shower. The event was observed at the M.I.T. Volcano Ranch station, elevation 5800 ft, near Albuquerque, New Mexico. An array of scintillation counters was used to detect and measure air showers by the technique used in the earlier M.I.T. Agassiz experiment.[1] The main array was made up of 19 detectors arranged in a pattern of triangles as shown in Fig. 1. The area of each detector was 3.3 m^2, and the spacing of adjacent detectors was 442 m. The area enclosed by the array was 2 km^2, but the sensitive area for detecting very large showers was considerably greater. An additional detector shielded by 10 cm of lead sampled the penetrating component of showers.

The event to be described was one of two, nearly equal in size, which were the largest observed in the period of operation September, 1959, to May, 1960. The total on-time of the equipment during that interval was about 180 days. The particle densities (particles/m^2) registered at the various points of the array are given in Fig. 1. The shower core struck several hundred meters outside the array boundary.

We found the direction of the shower axis by making a least-squares fit of the observed arrival times to those expected for a plane shower front. The values 41°, 41°, and 70° were found for the zenith angle, declination, and right ascension, respectively. The deviations of the ob-

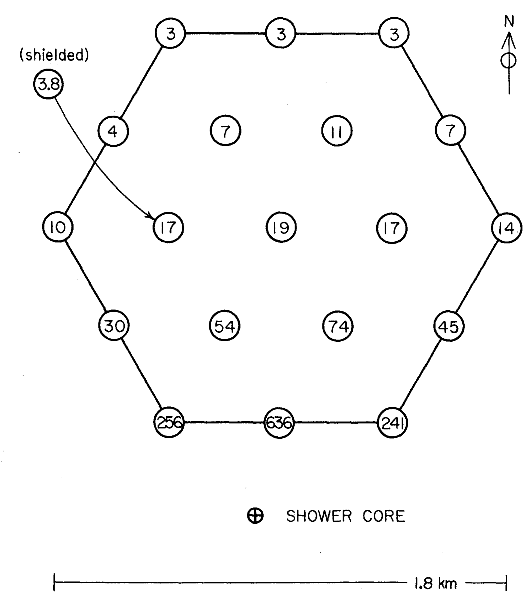

FIG. 1. Diagram of the Volcano Ranch 2-km^2 array, showing the location of the shower axis and measured densities in particles/m^2 for this event, No. 39 565. The shielded detector was located very near the indicated main detector.