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Abstract

280 MeV/nucleon nitrogen ion beam was stopped in a beryllium target. Radioactive isotope C^{11} (half life 20.34 min) has been produced by the fragmentation of the incident ion. We call this phenomenon "Auto Activation".

The phenomenon of induced radioactivity due to penetrating beams of fast particles of low atomic number (e.g. protons, helium ions) has been known for nearly four decades. A nuclear reaction between the incident nucleus and the target nucleus results in the observed radioactivity of the products. Simple fragmentation of the impinging nucleus, irrespective of the changes in the target nucleus, is well known. If the fragment is radioactive we call the process "Auto Activation".

In August 1971, fully stripped nitrogen ions were successfully accelerated in the Berkeley Bevatron (1) to various energies up to a maximum of 2.57 GeV/nucleon. We wanted to study the auto activation of incident nitrogen ions at 280 MeV/nucleon by bombarding a beryllium target. In particular, the object of the experiment was to study the formation of the radioisotope C^{11}, a positron emitter of 20.34 minutes half life.

Approximately 2.7×10^6 N^{7+} particles of energy 280 $\pm$ 10 MeV/nucleon were allowed to be stopped by a slab of spectroscopically pure beryllium metal (impurities less than 0.1%). The exposure time was 13 minutes. After a seven minute delay, gamma-ray spectra from the beryllium sample were studied with a scintillation spectrometer, that consisted of an 8-in diameter by 4-in thick NaI(Tl) crystal and a digital-gain-stabilized 400-channel pulse height analyser. The very low and constant background of the spectrometer system (48 c/min in the 511 keV peak region) enabled precise measurement of the small counting rate encountered.

The only gamma-activity observed in this beryllium sample produced a peak at positron-annihilation energy, 511 keV. Analysis of the required set of spectra confirmed the formation of two radioactive components with half life 10.1 minutes and 20.34 minutes corresponding to N^{13} and C^{11} respectively.

The depth-activation distribution for C^{11} was measured in another experiment where the nitrogen beam was allowed to impinge on a stack of beryllium absorbers, each 0.5 cm thick. The counting rates are shown in figure 1 as a function of the depth in beryllium. No measurable radioactivity was detected at all in the first 10 gm/cm^2 of beryllium. Most of the C^{11}-activity was concentrated in a fairly sharp peak near the range of N^{7+} particles in beryllium. A correction in the beam energy entering beryllium target had to be made due to intervening beammonitoring device. The corrected beam energy was 250 MeV/nucleon and its range in beryllium is about 13.0 gm/cm^2. Again no activity was found beyond 16 gm/cm^2 of beryllium.

These results generally agree with the idea that radioactivities observed, through the formation of C^{11} and N^{13}, are due to the fragmentation of N^{7+} ion. When a moving N^{7+} ion collides with a resting $^{9}_{4}Be$ atom, the general result is the fragmentation of each. It is not likely that a beryllium nucleus could capture a sufficiently large fragment of fast nitrogen to become C^{11}. The fragments of nitrogen, e.g. C^{11}, keep moving with almost the same velocity (1, 2, 3) as the N^{7+} ion, in the forward direction until they come to rest.

The total inelastic cross section for nuclear interaction (5) together with the probability of formation of a fragment with a given atomic and mass number can be written as

$$\sigma = \mathcal{P}_{Z,A}\, \pi R_o^2 \,(A_i^{1/3} + A_t^{1/3} - 1.7)^2 \qquad (1)$$

where $A_{i,t}$ is the mass number of the incident ion or the target atom, $R_o = 1.45 \times 10^{-13}$ cm and $\mathcal{P}_{Z,A}$ is the probability of obtaining a fragment with atomic number Z and mass number A in a given collisional product. From the present experiment we find $\sigma = 17$ millibarns and thus for C^{11} we get $\mathcal{P}_{6,11} = 0.03$. For N^{13}, $\sigma = 6$ millibarns.

We have also irradiated a stack of polyethylene absorbers by N^{7+} ion beam at 280 MeV/nucleon. Analysis of data agreed with our expectation of the appearance of radioactivity all along the path of the beam, since the resting carbon nuclei were expected to give rise to slow C^{11} nuclei. However at the end of the range of nitrogen ion there was a small peak in the C^{11} activity which we believe is an effect due to auto activation. More detailed analysis and possible conclusions will be reported soon. Finally, we have induced N^{13} and C^{11} activities in a target that contained three aluminum discs of thickness 1.27 cm each, followed by a stacked set of beryllium discs. The beryllium discs were analysed for C^{11} and N^{13} activation. It is interesting to note that in this sample the N^{13} radioactivity was found to have a different depth distribution than C^{11} activity, more of the former depositing at a smaller depth in the beryllium absorber.

Detailed calculations and further analysis of the experimental data are in progress and will be reported soon.

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References

1. Grunder, H. A., Hartsough, W. D., and Lofgren, E. J., Acceleration of Heavy Ions at the Bevatron (to be reported in Science).

2. Powell, C. F., Fowler, P. H., and Perkins, D. H., The Study of Elementary Particles by the Photographic Method, Section 16, p. 609, Pergamon Press Inc., New York, 1959.

3. Curtis, S. B., Semiannual Report, Donner Laboratory, University of California, Berkeley, UCRL-18347, pp 171-174, 1968.

4. Heckman, H. H., Lawrence Radiation Laboratory, University of California, Berkeley, California (to be reported in Science).

5. Waddington, C. J., The Composition of the Primary Cosmic Radiation, pp 1-46, 1960, Progress in Nuclear Physics, Vol. 8, editor, O. R. Frisch, Cavendish Laboratory, Cambridge.

Figure Legend

Fig. 1. Curve shows that C^{11}, resulting from the fragmentation of N^{7+} ions impinging on a Beryllium target, is deposited mostly at a particular depth.

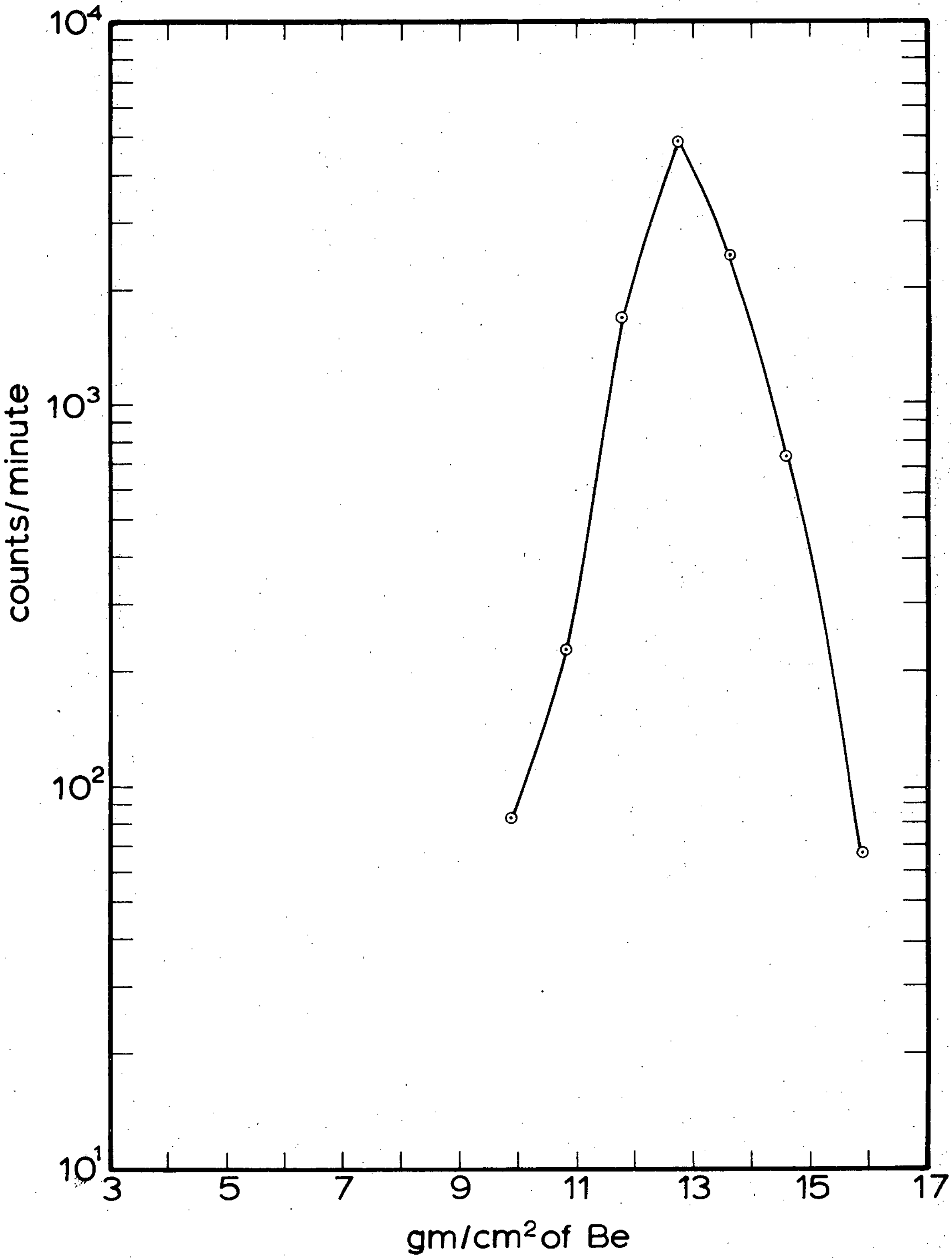

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Fig. 1

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