A preponderance of collisions outside the nuclear radius would have two consequences: It would mean that direct reactions are favored, since collisions in the surface would make compound nucleus formation less likely. Also, the Coulomb barrier for nuclear reactions is expected to corrrespond to a larger radius than C, in particular with respect to direct reactions.

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Excitation Function for the $Al^{27}(d,\alpha p)Na^{24}$ Reaction Between 0 and 28.1 Mev

P. A. Lenk and R. J. Slobodrian
Synchrocyclotron Laboratory, Nuclear Physics Division, Physics Department, Comisión Nacional de Energía Atómica, Buenos Aires, Argentina

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The excitation function for the $Al^{27}(d,\alpha p)Na^{24}$ reaction has been measured between 0 and 28.1 Mev. The external beam facilities of the Buenos Aires 71-in. synchrocyclotron were used together with the stacked-foil technique. Between 19 and 28.1 Mev present results are more precise than those previously obtained, showing that the maximum of the cross section is located at 24.25 Mev with a value of 51.4 mb.

1. INTRODUCTION

The excitation function for the $Al^{27}(d,\alpha p)$ reaction as a function of energy was measured previously between 0 and 190 Mev by Batzel *et al.*[1] using the external beam of the Berkeley 60-in. cyclotron (from 0 to 19 Mev) and the beam of the Berkeley 184-in. synchrocyclotron. Their measurements exhibit a sharp peak between 20 and 25 Mev. They used the stacked-foil technique and they point out that the peak is inherently ill-defined due to range straggling of the 190-Mev deuterons degraded by the absorber.

2. EXPERIMENT

We have used the recently available deflected deuteron beam facilities[2] of the Buenos Aires 71-in. synchrocyclotron, illustrated in Fig. 1, and the stacked-foil technique to measure the above-mentioned excitation function between 0 and 28.1 Mev. The aluminum foils were some 4.75 mg/cm² thick, cut in 4×4 cm pieces, weighed individually to 0.1 mg. The error in area was less than 0.5% and the error in thickness was therefore less than 0.8%. The aluminum was found to be at least 99.7% pure through spectrographic analysis.

The foils were stacked and aligned carefully, within 0.1 mm, in order to avoid geometry errors. They were compressed between two metal disks, one of them being perforated to permit the passage of the beam. The stack was irradiated at a distance of 20 feet from the machine (see Fig. 1), just in front of the scattering chamber. The pipe was pumped by the vacuum system of the machine. The deuteron beam was adequately focused by two pairs of alternating gradient quadrupole lenses. The beam spot is of the order of 1 cm². Beam current was 0.05 μA. Neutron background was low because there is no need of collimators or slits along the

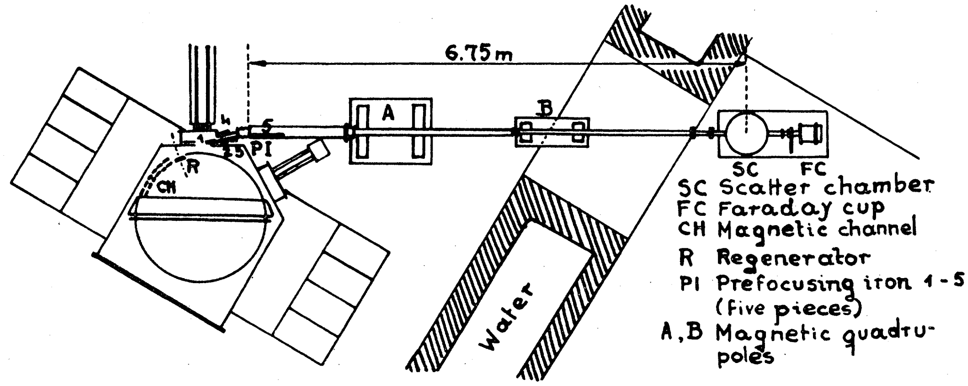

FIG. 1. External beam facilities of Buenos Aires 71-in. synchrocyclotron.

[1] Batzel, Crane, and O'Kelley, Phys. Rev. 91, 939 (1953).

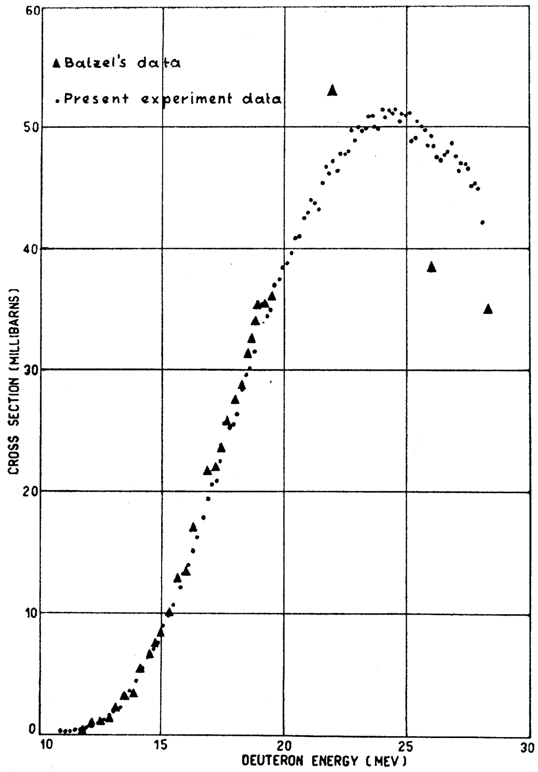

FIG. 2. Excitation function of $Al^{27}(d,\alpha p)Na^{24}$ reaction.

beam path.[2] This is achieved by keeping the beam size small and almost parallel with five pieces of iron located along the beam path. The iron is magnetized by the stray field of the machine. The beam direction was perpendicular to the stack within 1° and therefore the target thickness correction was negligible.

The experiment was preceded by three trial runs. The induced Na^{24} activity (approximately 15 hours half-life) was measured starting 14 hours after the irradiation was finished, with an end-window halogen-quenched Geiger-Müller counter and conventional scaling equipment. The counter high voltage was kept constant to 1% and therefore the activity of a standard source was always the same within counting statistics. Usual dead-time and decay corrections were made. The dead-time correction factor was obtained by the method of many sources. The maximum counting rate was 20 000 counts/min and the maximum dead-time correction was 11%. The background was of the order of 60 counts/min. The activity of the foils was followed for six days and no activity other than the one due to Na^{24} was found to interfere within 1%. For the foil thickness used, the activity increases linearly with thickness, and the data were normalized to a uniform thickness of 4.75 mg/cm^2.

The data of Batzel *et al.* between 0 and 19 Mev were considered trustworthy, and therefore our results were normalized to theirs in order to get absolute values of the cross section. The error due to counting statistics is of the order of 1% in the range between 19 and 28.1 Mev. The over-all error of the cross section is therefore less than 2%. Figure 2 and Table I contain the experimental results. The beam energy was determined independently with a standard current transmission measurement equipment: Faraday cup, absorbers, and electrometer. Figure 3 contains a diagram obtained during one of the measurements.

Aluminum range to energy conversion was performed using Bichsel's[3] recent experimental tables on proton ranges, converted to deuteron ranges by using the relation

$$R_{ZM}(E)=\frac{M}{M_pZ^2}R_p\left(\frac{M_p}{M}E\right),$$

where M and Z are, respectively, the mass and the charge of the particle, E is the energy, and M_p is the proton mass.

The original beam energy spread is estimated to be less than 0.2% but a precise figure could be given only

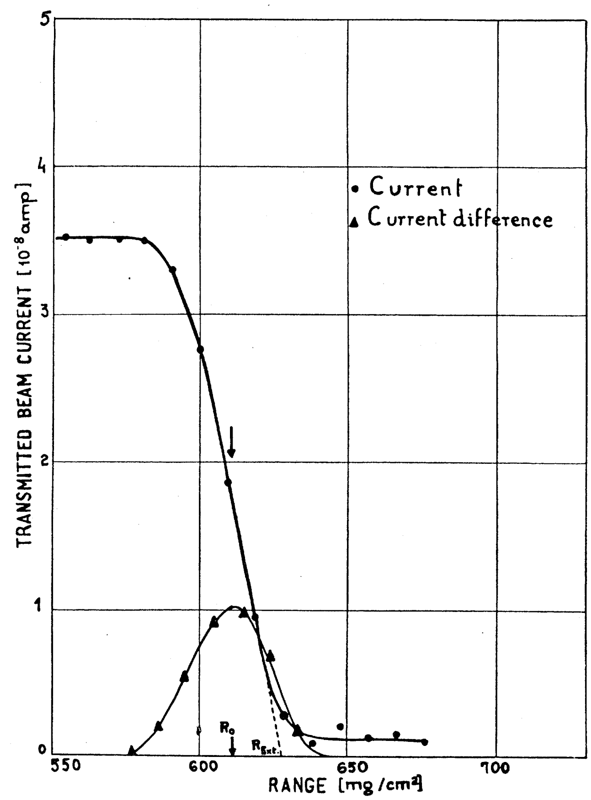

FIG. 3. Example of beam energy measurement data.

[2] J. Rosenblatt and R. J. Slobodrian, reported at the XXXIII Meeting of Asociación Física Argentina (to be published).

[3] H. Bichsel, Phys. Rev. **112**, 1089 (1958).

through magnetic analysis. This is consistent with the value of $(R_{ext}-R_0)/R_0=0.027$, where R_0 is the average range, and R_{ext} is the extrapolated range, taking into account that range straggling is of the order of 2.2%.

3. DISCUSSION

It is worth while to point out that the $Al^{27}(d,\alpha p)Na^{24}$ reaction is in competition with the $Al^{27}(d,p)Al^{28}$ reaction (2.3-min half-life). Data already obtained on the latter reaction by us show that the $(d,\alpha p)$ cross section starts rising when the (d,p) starts dropping. Although the shape of the excitation function for the $(d,\alpha p)$ reaction resembles the curves obtained through the compound nucleus assumption, additional work will be done using the nuclear scattering equipment in order to clarify the reaction mechanism, as it is suspected that direct reactions are important around 28 Mev.

TABLE I. Extract of values for the $Al^{27}(d,\alpha p)Na^{24}$ reaction cross-section.

Energy Mev	Cross section mb	Energy Mev	Cross section mb
11.0	0.35	21.1	44.0
12.0	0.60	22.1	46.4
12.9	1.61	23.0	50.0
14.0	4.38	24.1	50.8
15.1	9.04	24.25	51.4
16.1	14.0	25.1	51.2
17.0	20.6	26.1	48.2
18.1	26.4	27.0	47.6
19.1	35.5	28.1	42.2
20.1	38.8		

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High Altitude Neutron Intensity Diurnal Variation*†

ROBERT C. HAYMES
New York University, University Heights, New York, New York
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Two balloon flights in which boron-trifluoride neutron counters were carried aloft were launched from Brownwood, Texas, during September, 1958. The flights attained altitudes of 86 000 and 79 000 feet at a conventional geomagnetic latitude of 41°N. They showed that the slow-neutron intensities in the atmosphere had decreased by about 12% since the time of minimum solar activity in 1954. They also show that this decrease was mainly in the low-energy end of the spectrum, as the mean free path for absorption had increased from 180±25 g/cm² to 240±30 g/cm². A high-altitude decrease apparently associated with the geomagnetic storm of September 25, 1958 was also detected. After achieving altitude, the balloons floated at a constant elevation through sunset. A sharp peak in the intensity which occurs just before sunset at balloon altitudes was detected on both flights. The origin of this phenomenon, which results in a doubling of the intensity for about 25 minutes, is unexplained, although some possible mechanisms are discussed.

INTRODUCTION

AN experimental search for a diurnal variation of cosmic-ray neutrons has been conducted at balloon altitudes in order to determine if primary neutrons exist in the cosmic radiation. These neutrons, if present, would originate in the sun. This is because of the relatively short half-life of the free neutron.[1] This 13-minute lifetime precludes a very distant origin for all but the most energetic neutrons. Extremely relativistic particles could reach the earth from elsewhere in the galaxy because of time-dilatation effects, but their numbers are likely to be quite small.

Since the distance between the sun and the earth is only 8.3 light-minutes, a fairly fast neutron does have a reasonable probability of surviving the trip. Of course, this assumes that these neutrons are produced high up in the solar corona, so that their probability of absorption within the sun is small.

Because neutrons are uncharged, they propagate in straight lines, like light. Thus, the existence of solar neutrons would be expected to give rise to day-night and eclipse effects.[2]

Several possible processes leading to neutron production by the solar corona have been considered. Biermann, Haxel, and Schlüter[3] have shown that if a solar flare

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[1] J. M. Robson, Phys. Rev. **83**, 349 (1951).

[2] Swetnick, Neuburg, and Korff, Phys. Rev. **86**, 589 (A) (1952).

[3] Biermann, Haxel, and Schlüter, Z. Naturforsch. **6a**, 47 (1951).