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Excitation Function of the $Al^{27}(d,p)Al^{28}$ Reaction between 2.2 and 12.6 MeV

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The excitation function of the $Al^{27}(d,p)Al^{28}$ reaction has been measured using the stacked-foil technique between 2.2 and 12.6 MeV. The absolute calibration was done by measuring simultaneously the excitation function of the (d,p) and the $(d,\alpha p)$ reactions on Al^{27}, and comparing the results of the $(d,\alpha p)$ reaction with those of Batzel *et al.* The peak value of the excitation function was found to be located between 7 and 8 MeV, with a value of 239 ± 29 mb. The half-life of the Al^{28} was measured, giving a value of 2.28 ± 0.06 min. The deuteron beam used was that of the Buenos Aires synchrocyclotron.

1. INTRODUCTION

BETWEEN 0 and 1.75 MeV the excitation function of the $Al^{27}(d,p)Al^{28}$ reaction was measured by Lawrence.[1] In this work it was measured between deuteron energies of 2.2 and 12.6 MeV; it was very difficult to obtain accurate values for greater energies, owing to the interference of the 9.5-min half-life of the Mg^{27} formed by the (d,pp) reaction on Al^{27}.

2. EXPERIMENTAL FACILITIES

The facilities of the external beam of the Buenos Aires synchrocyclotron will not be described here since this has already been done elsewhere.[2,3] The stacked foils were irradiated at the entrance of the beam into a scattering chamber; the displacement of one foil from another in the stack was less than 1 mm. The energy of the deuteron beam was determined by measuring the mean range of the deuterons in Al. The range of deuterons in Al was obtained by converting the experimental proton ranges of Bichsel.[4] With different conditions of the machine, the energy of the beam could be changed between 27.3 and 28.1 MeV. The resultant estimated error of the energy measurement was ± 0.3 MeV.

The foils used were 3×3 cm in area and approximately 5 mg/cm^2 in areal density. The fluctuations in area of each foil were smaller than 0.7%, in weight smaller than 0.2%, and in thickness smaller than 0.9%. The Al had a purity of 99.7%. In order that a quick change of foils in front of the detector and a reproducible geometry could be obtained, the foils were mounted on two trays with a capacity of nine each. The detectors were two end-window Geiger-Müller counters, halogen-quenched, with the corresponding voltage supplies and scalers. The activities were registered in a two-channel Brush magnetic recorder that inscribed 50 100, and 1000 counts of the scalers as pulses of different height. In this way, although Al^{28} is comparatively short-lived, 18 foils could be measured almost simultaneously, covering approximately 6 MeV of the excitation function. The dead time corrections were performed using a nomogram obtained by measuring the radioactive decay of In^{116}, having a maximum rate of 20 000 counts in 10 sec. The background, because of the large activities of the foils, hence short counting times, was negligible in most cases.

3. EXPERIMENTAL RESULTS

To cover the excitation function ten stacks of foils were irradiated, taking care, in all cases, that the set of 18 foils which could be measured afterwards, covered the maximum of the function. Each time the stacked foils were irradiated for about fifteen seconds, with a current of approximately 0.01 μA. The measurement of the activities started usually five minutes after the end of the irradiation. Each foil was followed through five half-lives with measurements of 10 sec separated by intervals of 2.5 min. The initial activities, previously corrected for dead time, were obtained by extrapolating to time zero (end of the irradiation), the decay curve of each foil. These values were normalized by the weight of the foils and the geometry of the counters. Finally all the excitation curves were normalized by area, considering the area enclosed by one of the curves as unity. To find an average curve, the activities obtained for each curve was measured with intervals of 0.2 MeV, the corresponding results were averaged and the standard deviations were determined. The neutron-produced activity was in all cases negligible, as was demonstrated by irradiating a stack of foils, and afterwards measuring the activity in the foils which were beyond the deuteron range. For each one of the initial activities obtained, the half-life of the Al^{28} was determined; the average of those values gave for the Al^{28} a half-life of 2.28 ± 0.06 min, the error being the standard deviation of the set of values obtained in this experiment. To obtain the excitation function in absolute value a stack of foils was irradiated for thirty minutes and afterwards the $Al^{27}(d,p)Al^{28}$ and the $Al^{27}(d,\alpha p)Na^{24}$ excitation functions were measured; the results of the latter were compared with those of Batzel *et al.*[5] In this

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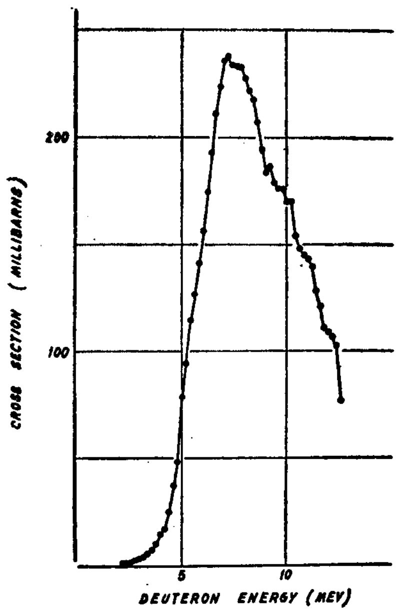

FIG. 1. Excitation function of the Al^{27}-$(d,p)Al^{28}$ reaction.

way a constant was obtained proportional to the integrated flux of deuterons, the efficiency of the counting system, and the number of nuclei of Al^{27} in the target. With this number it was possible to express in mb the cross section for the excitation function of the (d,p) reaction in Al^{27}. Since the data of Batzel *et al.*[5] had an estimated error of 10% it was thought justified to make only one simultaneous measurement of the excitation function of the (d,p) and $(d,\alpha p)$ reactions on Al^{27}.

Table I contains the data obtained expressed as number of disintegrations per ten seconds, and in millibarns as a function of the deuterons energy; the data are represented in Fig. 1. The error in the absolute value of the cross section at the maximum of the excitation function is some 12%.

TABLE I. Cross section of the $Al^{27}(d,p)Al^{28}$ reaction.[a]

E	A	e	r	E	A	e	r
2.2	0.50		1	7.6	116.57	2.92	233
2.4	0.50		1	7.8	116.03	3.52	232
2.6	0.64		1	8.0	113.75	4.34	228
2.8	1.20		2	8.2	111.00	3.06	222
3.0	1.50		3	8.4	108.80	3.60	218
3.2	2.00		4	8.6	103.50	2.01	207
3.4	2.70		5	8.8	97.39	2.60	195
3.6	3.75	0.15	7	9.0	91.81	4.56	184
3.8	5.13	0.87	10	9.2	93.29	3.02	187
4.0	7.35	0.75	15	9.4	89.58	2.79	179
4.2	8.50	1.52	17	9.6	88.33	2.33	177
4.4	12.50	1.60	25	9.8	88.27	4.11	177
4.6	18.63	1.75	37	10.0	85.17	2.74	170
4.8	24.25	2.92	48	10.2	85.15	3.80	170
5.0	39.42	4.60	79	10.4	77.36	2.66	155
5.2	47.37	5.51	95	10.6	74.20	3.54	148
5.4	57.38	6.40	115	10.8	72.70	3.60	145
5.6	63.46	5.55	127	11.0	71.93	5.20	144
5.8	70.69	4.98	141	11.2	70.00	4.85	140
6.0	78.19	4.45	156	11.4	64.17	4.32	128
6.2	87.25	4.57	174	11.6	60.67	4.70	121
6.4	96.50	3.97	193	11.8	55.70	5.90	111
6.6	105.69	3.96	211	12.0	54.75	7.25	110
6.8	111.94	3.11	225	12.2	53.60	8.60	107
7.0	117.94	3.22	237	12.4	51.50	11.00	103
7.2	119.10	2.72	239	12.6	38.70		77
7.4	117.08	2.89	234				

[a] A multiplied by 10^3 is the initial activity in ten seconds, E is the energy of the deuterons expressed in MeV, e is the standard deviation of each A, and r is the cross section of the reaction in mb.

4. DISCUSSION

The value obtained for the half-life of Al^{28} agrees with the results of Bartholomew *et al.*[6] Excitation functions for reactions of the type (d,p) and (d,n) can be fitted using the Peaslee model.[7] This model, however, cannot explain the fine structure of the curve. Peaslee assumes that if the process involves a great number of levels, in first approximation the phase of the deuteron wave function at the surface of the target nucleus will fluctuate statistically. This is not completely true for Al^{28}, since for relatively low excitation energies it more truly has groups of levels rather than a continuum.

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