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Absolute Differential Cross Sections over the Entire Angular Range for the Reaction $^{3}H(d,n)^{4}He$ at 7.0 and 10.0 MeV

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ABSOLUTE DIFFERENTIAL CROSS SECTIONS OVER THE ENTIRE ANGULAR RANGE FOR THE REACTION $^3H(d,n)^4He$ AT 7.0 AND 10.0 MeV

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ABSTRACT

Differential cross sections for the reaction $^3H(d,n)^4He$ have been measured at 7.00 and 10.00 MeV using the time-of-flight technique. By measuring both $^3H(d,n)^4He$ and $^2H(t,n)^4He$ at the same center of mass, energy-complete distributions between 0° and 180° have been obtained. The absolute scales have been established within ± 1.5% by using the accurate $^2H(t,^4He)n$ cross sections at 20.0 MeV as a standard.

I. INTRODUCTION

Inconsistencies in previously published cross sections for the $^3H(d,n)^4He$ reaction,[1] especially suspected back-angle problems, made it necessary to measure complete distributions rather than extrapolating between 140° and 180°.

II. EXPERIMENTAL

The basic experimental arrangement and the general experimental procedure have been described in references 1, 2, and 3, and some improvements in references 4 and 5. In addition, there were two essential changes with regard to back-angle data:

1. All angles up to 130° were measured with the same geometry and shielding (contrary to the procedure in reference 1).
2. Back-angle data up to 180° could be covered by interchanging the particles in the entrance channel and maintaining the same center-of-mass energy.

Since data could be taken between 0° and about 130° in the lab system, this means an overlap of independently measured data for more than 50% of the distribution. Thus systematic errors could be recognized and eliminated. For this experiment the reaction $^3H(d,n)^4He$ was assumed to be the main reaction, whereas $^2H(t,n)^4He$ supplied the back-angle data. The scale for the cross sections was obtained from the accurate charged-particle cross sections of the $^2H(t,^4He)n$ reaction at 20.00 MeV.[6] This was done by remeasuring the corresponding angles of the $^3H(d,n)^4He$ distribution at the corresponding energy of 13.356 MeV. Measuring more than one angle not only improves the statistical quality of the scale factor, but gives a redundancy which allows a check for systematic errors, e.g., in the efficiency curve, in the background subtraction, etc.

III. RESULTS AND ERRORS

Whereas 7 MeV was chosen to join what was believed reliable data at lower energies[7] (see also a recent compilation[8]), 10 MeV was the maximum energy for which the complete distribution could be measured due to the limited energy of the accelerator and the required energy of 14.975 MeV for the inverse reaction. The 7-MeV data were taken in one run only, whereas the 10-MeV data are combined results of data taken on four occasions between October 1971 and August 1975. The agreement between these data sets, taken with the same detector but with different mechanical setup, proved the long-term reproducibility of the data. The measured absolute cross sections are given in Tables I and II. The error includes both statistical errors and uncertainties in the background subtraction. It does not include errors in the shape of the efficiency curve. Those are smaller than ± 1% except for energies above 29 MeV and between 17.5 and 20 MeV.

Also not included are errors due to the angle uncertainty of ± 0.05° and due to a deviation of the actual 0° point from the assumed one. Although the 0° point can be set within ± 0.05° to the ideal position, changes in the beam steering were found to give deviations up to 0.2°. This deviation is insignificant for the data reported here since the cross section does not change very much with angle.

Finally, there is an adjustment error for the $^{2}H(t,n)^{4}He$ part of the data. It is thought to be less than 1%. This estimate is based on the fact that the best adjustment factor for the 7.0-MeV distribution is only 0.7% bigger than the best for the 10.0-MeV distribution.

The scale error, consisting of the claimed precision of the standard, of the adjustment error to the standard, and of the reproducibility error, adds up to 1.5%.

The present data at 7 MeV are incompatible with those of Bame and Perry.[7] A similar disagreement has been reported previously[9] for their 6-MeV distribution, namely, too big a ratio $\sigma(120°)/\sigma(0°)$ by 18%. A comparison with the previous data of McDaniels et al.[1] shows their data are too high beyond 90°, e.g., the ratio of $\sigma(130°)/\sigma(0°)$ is too high by 28% at 7 MeV and by 14% at 10 MeV. Rather good, both in scale and shape, is the agreement with Stewart's et al.[10] back-angle data at 9.9 MeV.

The data evaluated by Liskien and Paulsen,[8] who cover energies up to 10 MeV, deviate increasingly from our shape for angles bigger than 90° and their scale is lower by about 7%. The difference in shape is somewhat surprising, as the data of Goldberg and LeBlanc[11] at 10.2 MeV, on which this evaluation depends, are in reasonable agreement with our new data.

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TABLE I

CENTER-OF-MASS CROSS SECTIONS FOR THE REACTION

$^3H(d,n)^4He$ AT 7.00 MeV

		$^3H(d,n)^4He$ at 7.00 MeV		$^2H(t,n)^4He$ at 10.483 MeV	
θ_{Lab}	θ_{cm}	σ_{cm}	Error %	σ_{cm}	Error %
0.0	0.0	19.38	1.0	---	---
5.0	5.9	18.55	1.2	---	---
10.0	11.8	16.59	1.0	---	---
15.0	17.7	13.84	1.3	---	---
20.0	23.6	10.67	2.0	---	---
25.0	29.4	8.21	0.9	---	---
30.0	35.25	6.56	1.1	---	---
	36.5	---	---	6.24	2.0
	41.0	---	---	5.65	1.4
40.0	46.75	5.42	2.0	---	---
	47.1	---	---	5.47	1.2
	52.4	---	---	5.42	1.4
50.0	58.05	5.79	1.1	5.74	1.1
60.0	69.1	5.81	0.9	5.97	1.2
70.0	79.85	4.96	2.0	5.18	1.2
75.0	85.15	4.51	1.4	4.52	1.1
	87.15	---	---	4.30	1.0
80.0	90.35	3.92	1.1	---	---
90.0	100.5	3.29	1.1	3.26	1.4
95.0	105.5	3.20	1.3	3.18	1.2
100.0	110.3	3.24	2.0	3.31	1.1
105.0	115.1	3.54	1.4	3.53	1.2
110.0	119.9	3.93	2.5	3.86	1.2
120.0	129.1	4.68	1.2	4.65	1.0
130.0	138.0	5.40	1.1	5.34	1.2
131.8	139.6	5.43	1.1	---	---
	144.6	---	---	5.60	1.1
	155.25	---	---	6.20	1.3
	167.65	---	---	6.35	1.3
	180.0	---	---	6.37	1.0

TABLE II

CENTER-OF-MASS CROSS SECTIONS FOR THE REACTION

$^3H(d,n)^4He$ AT 10.00 MeV

		$^3H(d,n)^4He$ at 10.0 MeV		$^2H(t,n)^4He$ at 14.975 MeV	
θ_{Lab}	θ_{cm}	σ_{cm}	Error %	σ_{cm}	Error %
0.0	0.0	17.07	1.0	---	---
10.0	12.1	13.26	0.9	---	---
14.8	17.9	10.01	1.5	---	---
20.0	24.1	6.74	1.5	---	---
25.5	30.7	4.24	1.1	---	---
27.1	32.6	3.72	1.5	---	---
29.4	35.3	3.25	1.3	3.40	4.4
30.0	36.0	3.15	1.5	---	---
33.3	40.0	2.97	1.1	3.06	4.9
36.5	43.7	3.04	1.1	---	---
	44.3	---	---	3.20	3.4
40.0	47.8	3.55	1.5	---	---
41.1	49.05	3.70	1.0	3.72	2.4
43.9	52.3	4.18	1.5	---	---
44.8	53.3	4.33	1.2	4.30	2.0
46.3	55.0	4.50	1.5	---	---
48.3	57.3	4.79	0.9	4.74	1.8
50.0	59.25	4.97	1.1	4.86	2.0
52.7	62.3	5.04	0.9	5.13	1.4
56.7	66.8	5.16	1.0	5.13	1.5
60.0	70.45	5.08	1.5	5.05	1.7
60.7	71.25	5.04	1.1	5.02	1.1
	80.0	---	---	4.10	1.3
70.0	81.4	3.92	1.5	---	---
77.2	89.0	2.96	1.5	2.95	1.1
	91.9	---	---	2.65	2.5
84.0	96.0	2.30	1.2	---	---
	97.3	---	---	2.23	2.5
90.0	102.1	2.04	1.5	2.05	2.5
	104.2	---	---	2.02	1.8
94.3	106.4	2.00	1.6	---	---
	108.2	---	---	2.05	2.3
100.0	111.9	2.22	1.5	---	---
	113.4	---	---	2.29	2.3
	114.6	---	---	2.41	1.4
	118.5	---	---	2.62	2.3
108.5	120.0	2.78	1.2	---	---
110.0	121.3	2.90	1.5	---	---
	123.2	---	---	3.00	2.3
	125.3	---	---	3.16	1.3
118.0	128.65	3.38	1.4	3.42	1.3
	139.3	---	---	4.13	1.3
131.7	140.7	4.11	1.5	4.24	1.2
	145.1	---	---	4.51	1.4
	147.7	---	---	4.70	1.1
	153.8	---	---	5.18	1.1
	160.4	---	---	5.75	1.2
	167.6	---	---	6.54	1.0
	180.0	---	---	7.20	1.5