LA-8538

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Photocomposition by Diana Ortiz and
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**UNITED STATES
DEPARTMENT OF ENERGY
CONTRACT W-7405-ENG. 36**

LA-8538

UC-34c
Issued: October 1980

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ABSTRACT

From an energy-dependent analysis of all available data, Legendre coefficients are derived that allow a consistent presentation of the differential cross sections of the reaction ^{2}H(d,n)^{3}He between 20.0 and 39.8 MeV. At energies above 25 MeV where no direct data are available, these coefficients predict cross sections of the neutron productions at 0° to better than ± 10%.

I. INTRODUCTION

Previous evaluations of the differential cross sections of the reaction ^{2}H(d,n)^{3}He covered deuteron energies between 0.02 to 10 MeV[1] and 3 to 20 MeV,[2] respectively. Above 20 MeV, the amount of data is sparse and mainly restricted to back-angle data. In recent years, there has been increased interest in neutron data up to 50 MeV[3] and, consequently, in neutron sources for higher energies.[4] For this reason, neutron production at 0° is important. At this angle there are no experimental data above 27.5-MeV deuteron energy. However, there is a set of several incomplete angular distributions measured by the charged-particle method for energies up to 39.8 MeV.[5] Using these charged-particle data and the previously found[6] energy dependence of the total ^{2}H(d,n)^{3}He cross section, Legendre coefficients that vary smoothly with energy were derived. These coefficients predict the 0° differential cross sections for deuteron energies up to 40 MeV.

II. PROCEDURE

A previous extrapolation of the 0° excitation function of the reaction ^{2}H(d,n)^{3}He from 17 MeV to 25 MeV[2] using one incomplete angular distribution was very successful. At 24.3 MeV, the predicted value was later verified experimentally within (1.2 ± 3.7)%.[7]

This report depends heavily on the charged-particle data of Fegley.[5] Confidence in the usefulness of these data was suggested by the good agreement between the integrated cross sections of the individual distributions[5] and the predictions of the total cross section[6] (Fig. 1). The confidence in these data was increased during the analysis, when no serious systematic deviations between the experimental and the smooth excitation functions were observed (Fig. 2).

The final analysis had to satisfy:

(1) the consistent presentation of Fegley's data,[5]
(2) the agreement of the integrated cross sections with the calculated predictions,[6]
(3) the smooth variation of the Legendre coefficients (no sharp resonances in ^{4}He in this energy interval),
(4) the smooth connection to the Legendre coefficients below 20 MeV,[2] and
(5) the smooth extrapolation of the excitation functions to data from an angular distribution at 51.5 MeV[8] (for ^{3}He lab angles of 10° and larger).

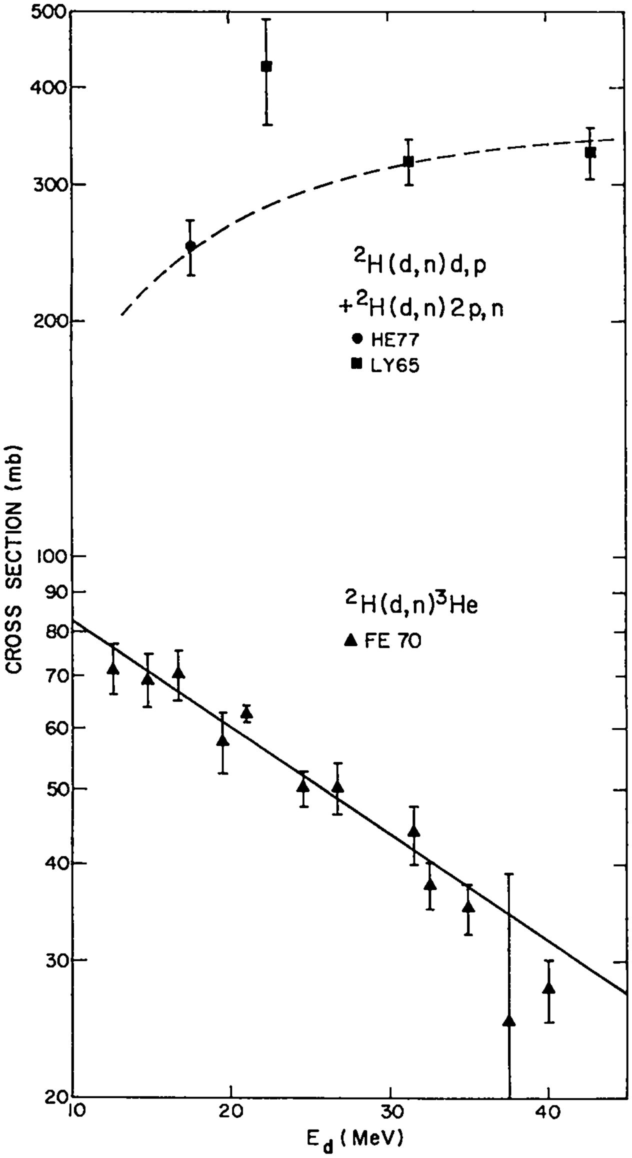

Fig. 1.
Energy dependence of the total cross sections for the neutron production by the d-D interaction. The solid line is the prediction of Ref. 6 for the two-body reaction and the dashed curve is to guide the eye. FE70 is from Ref. 5, HE77 is from Ref. 9, and LY65 is from Ref. 10.

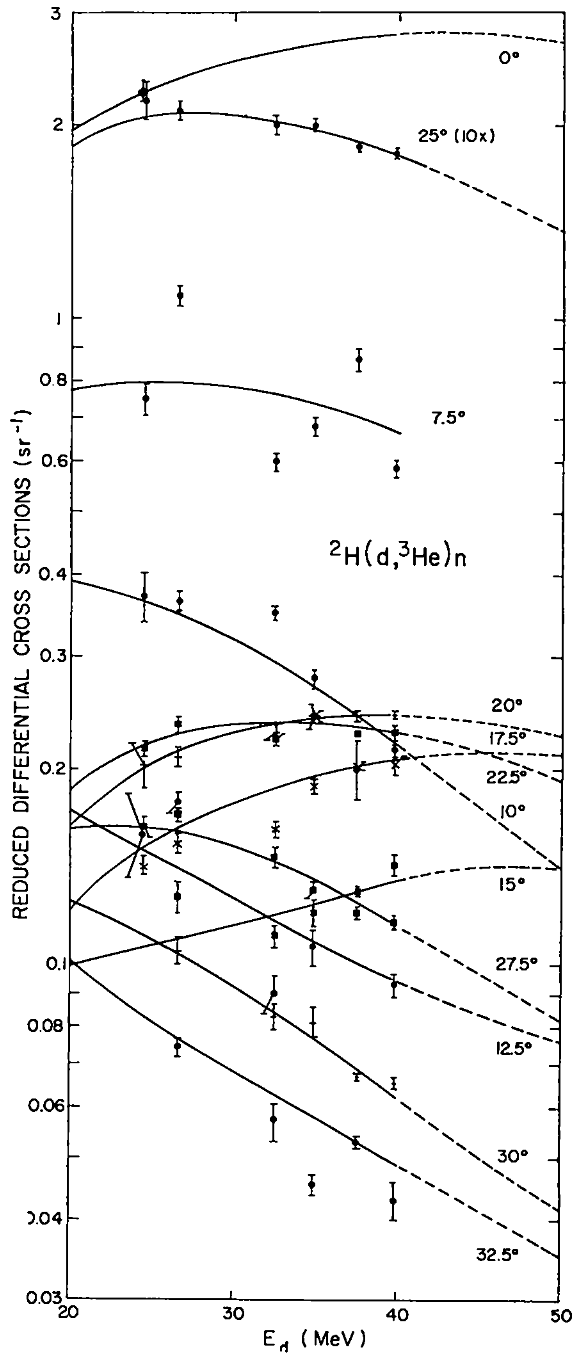

Fig. 2.
Excitation functions of the differential cross sections of the ^{2}H(d,^{3}He)n reaction. The angles are the lab angles of ^{3}He. The cross sections are reduced center-of-mass values (they are multiplied by the square of the relativistic wave numbers). The data points are from Ref. 5, except for the point at 0°, which is from Ref. 7. The error bars of Ref. 5 include statistical errors only. The dashed curves give the extrapolation to the data of Ref. 8.

III. RESULTS AND DISCUSSION

The analysis results are given in Table I. The excitation functions calculated from these coefficients are shown in Fig. 2 together with the experimental data. The experimental data errors include only the statistical errors. At larger angles, the additional errors increase

TABLE I

$^2H(d,n)^3He$ RECOMMENDED VALUES FOR σ(O° CM), LEGENDRE COEFFICIENTS A_l, AND σ (TOTAL)

E_d (MeV)	σ_0 (mb/sr)	A_0	A_2	A_4	A_6	A_8	A_{10}	A_{12}	A_{14}	A_{16}	σ_t[b] (mb)
20.0[c]	40.8	117.5	192.4	241.0	270.1	111.5	40.4	12.5	8.4	6.2	60.1
22.0[c]	39.5	113.8	188.3	228.7	275.0	119.5	45.4	14.1	8.9	6.3	56.4
24.5	38.0	109.6	183.9	217.8	279.4	126.9	51.0	16.1	9.5	5.8	52.2
25.3	37.5	108.2	182.9	214.4	280.3	129.4	52.9	16.8	9.6	5.5	50.9
26.6	36.8	106.3	180.7	209.2	281.5	133.8	55.6	17.8	9.9	5.2	48.8
30.0	34.8	100.9	175.4	198.9	282.6	143.7	62.7	20.8	10.6	4.4	43.9
32.5	33.3	97.2	171.4	191.3	282.1	151.6	68.1	23.3	11.1	3.9	40.5
34.9	31.8	94.0	168.5	185.1	280.2	158.7	72.7	25.9	11.4	3.5	37.6
37.5	30.2	90.3	164.7	177.9	277.4	167.0	78.7	29.1	11.8	3.1	34.6
39.8	28.9	87.3	162.3	173.0	274.6	172.5	83.3	32.1	12.1	2.8	32.2

[a]The coefficients are multiplied by 1000 to make the numbers easier to read. For uncertainties, see the text.
[b]Calculated values, see Ref. 6.
[c]By interpolation.

because of the reduced energy of the ^3He particles. Background subtraction also becomes difficult at the very forward angles. These facts explain the rather large deviations from the corresponding smooth curves. Although the solution fulfills the conditions of Sec. II, some systematic errors of the data will be carried into the solution. The most serious error is the ± 0.25° uncertainty of the 0° direction. This gives a systematic angular shift of more than 2° for center-of-mass angles > 60°. The additional angular uncertainty of ± 0.25° is claimed to be random and therefore less serious.

An error in the 0° direction will give the biggest percentage deviation at the slopes of the distribution. The maximum at 0° and that near 60° will not be affected as much. Therefore, 0° values derived from the present analysis should not depend strongly on such a systematic error. Consequently, the uncertainty of the 0° predictions will be <10% even at 40 MeV, decreasing to about 3% at 24.3 MeV where an experimental data point is available.[7] (It is surprising that between 12 and 40 MeV the cross-section ratio of the second to the first maximum stays practically constant at 0.094 ± 0.004.)

From Fig. 1 it can be concluded that the d-D reaction is not a useful source of monoenergetic neutrons at higher energies. The (total) cross section for neutron production by deuteron break-up increases with energy,[9,10] whereas that of the two-body reaction decays exponentially. At 40 MeV deuteron energy, the two-body cross section is <10% of that of the break-up cross section. Consequently, the signal-to-background ratio for monoenergetic neutron production will be quite small despite the strong forward peaking of the angular distributions.

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