Title
TOTAL REACTION CROSS SECTIONS FOR 22.4 MeV DEUTERONS

Authors
Wilkins, B.
Igo, G.

Publication Date
1962-10-10

UCRL-10500

University of California

Ernest O. Lawrence Radiation Laboratory

Berkeley, California

DISCLAIMER

UNIVERSITY OF CALIFORNIA
Lawrence Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

TOTAL REACTION CROSS SECTIONS FOR 22.4 MeV DEUTERONS

B. Wilkins and G. Igo

October 10, 1962

TOTAL REACTION CROSS SECTIONS FOR 22.4 MeV DEUTERONS

B. Wilkins and G. Igo

Lawrence Radiation Laboratory
University of California
Berkeley, California

October 10, 1962

The reaction cross section for deuterons is a subject of considerable interest. The deuteron is known to be a relatively-large, loosely-bound system subject to electric breakup processes[1] in collisions at interaction distances larger than the nuclear radius in heavy elements[2]. In addition nuclear breakup processes[3] at the nuclear surface in light elements have large cross sections[2]. If interactions occur at a larger radius[4] than is the case for alpha particles or protons, the total reaction cross section might be expected to be enhanced. Indeed, Hamburger, Cohen, and Price[2] have found that at about 15 MeV the deuteron breakup cross section is of the order of a factor of two larger than the predicted values for electric breakup or nuclear breakup[1,3]. The measurements reported in this Letter show that the reaction cross sections are apparently not enhanced by the large magnitude of the breakup-process cross sections. A comparison of 22.4 MeV deuteron reaction cross sections with 40 MeV alpha particle reactions cross sections (soon to be reported) show them to be almost identical for all elements investigated. The comparison is valid since the coulomb barrier effects are almost identical in these two cases.

The experimental apparatus used in the reaction cross section measurements (see Fig. 1) has been described in detail elsewhere[5] and will not be discussed here except where parameters of the experiment have been altered because of the change in the projectile. The raw cross section σ, obtained from the target-in and target-out measurements, is listed in Table I. Three

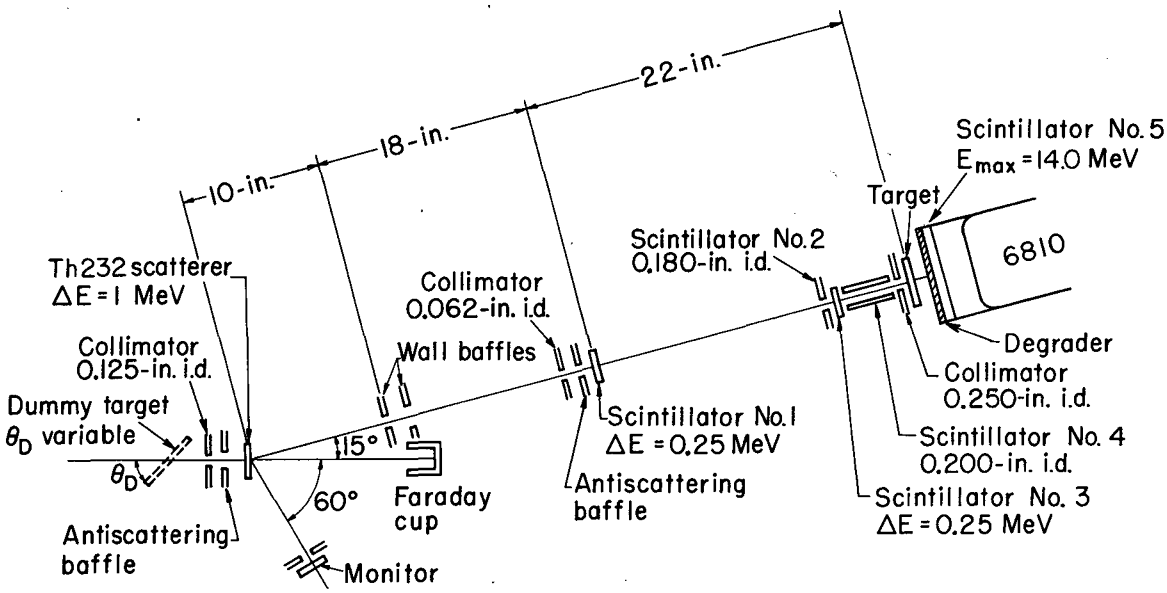


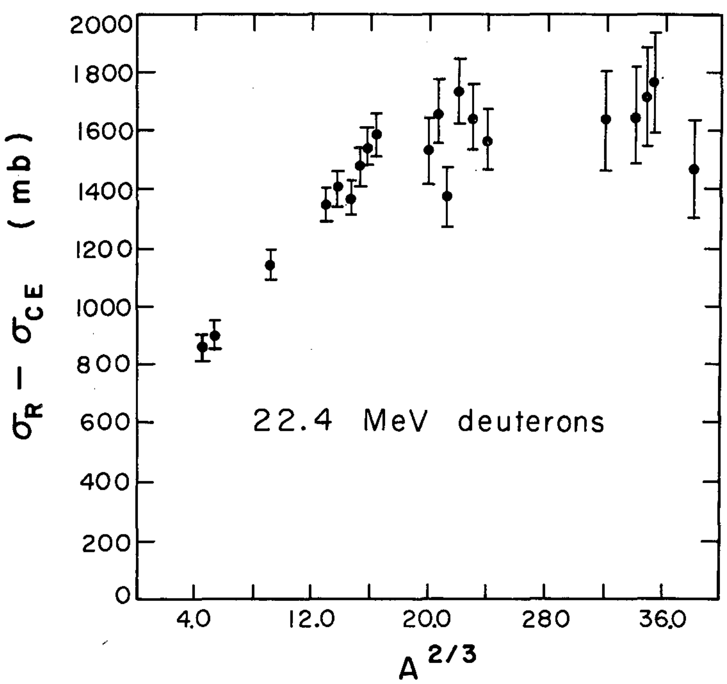
Fig. 1. Schematic diagram of the experimental area.

Table I. The raw cross section σ, the counter 3 scattering-out correction η_3, the inelastic scattering correction σ_{in}, the elastic scattering correction σ_{el}, and the non-elastic cross section $\sigma_R - \sigma_{CE}$.

Element	σ (mb)	η_3 (mb)	σ_{in} (mb)	σ_{el} (mb)	$\sigma_R - \sigma_{CE}$ (mb)
Be	858 ± 10	- 2 ± 4	60 ± 18	51 ± 3	865 ± 21
C	885 ± 18	- 4 ± 7	65 ± 18	50 ± 8	896 ± 28
Al	1098 ± 31	+ 2 ± 9	75 ± 13	41 ± 2	1134 ± 35
Cu	1537 ± 56	+ 7 ± 17	99 ± 16	104 ± 5	1539 ± 61
Zn	1595 ± 58	+ 7 ± 17	100 ± 25	108 ± 5	1594 ± 65
Ni	1486 ± 55	+ 7 ± 17	92 ± 25	94 ± 5	1491 ± 63
Rh	1899 ± 82	- 4 ± 27	82 ± 21	230 ± 11	1747 ± 89
Ag	1801 ± 81	+ 6 ± 27	78 ± 12	250 ± 12	1635 ± 87
Ti	1381 ± 57	-61 ± 20	85 ± 24	58 ± 9	1347 ± 66
V	1412 ± 56	-24 ± 19	85 ± 24	63 ± 9	1410 ± 64
Fe	1406 ± 61	-39 ± 21	90 ± 25	87 ± 14	1370 ± 70
Nb	1789 ± 80	-23 ± 27	90 ± 23	190 ± 22	1666 ± 90
Sn	1863 ± 101	-95 ± 36	79 ± 17	284 ± 33	1563 ± 117
Zr	1937 ± 96	-328 ± 34	94 ± 15	182 ± 27	1521 ± 106
Au	1773 ± 117	+ 9 ± 40	96 ± 22	246 ± 12	1632 ± 126
Pb	1891 ± 122	- 6 ± 40	95 ± 24	266 ± 40	1714 ± 136
Bi	1952 ± 121	0 ± 40	93 ± 23	272 ± 41	1773 ± 136
Th	1772 ± 147	-97 ± 53	95 ± 24	319 ± 48	1451 ± 165
Ta	1843 ± 128	-91 ± 46	95 ± 20	210 ± 31	1637 ± 140

principle corrections must be made to σ: A "dummy" foil is placed ahead of the counters when the target is out so that the energy incident on the stopping counter will be the same in the target-in and target-out measurements. The deuteron energy in counter 3 is therefore different for the two configurations. Fortunately the counter 3 scattering-out correction η_3 can be measured quite accurately[5]. A second correction σ_{el} to be considered is due those elastic events where scattering occurs outside of the solid angle subtended by counter 5, the stopping counter. The corresponding plane angle θ_5(lab) was set at 28.7° for light and intermediate elements. For elements heavier than tin θ_5 was set at 43.0°. The third correction σ_{in} is comprised from all inelastic events scattered into the solid angle subtended by the stopping counter. In order to facilitate the separation of elastic events from the inelastic events, a degrader foil is placed between the target and counter 5. The thickness of the degrader foil was adjusted so that 10.5 MeV protons and 14 MeV deuterons would be stopped by it. The correction σ_{in} will be due chiefly to (d,p), (d,d') and (d,pn) events. Correction for σ_{in} and σ_{el} have been estimated from the literature[2,6-11]. The elastic scattering data is the sum of shape elastic scattering σ_{SE} and compound elastic scattering σ_{CE}. The latter is not included in the measured quantity in these experiments. The final result $\sigma_R - \sigma_{CE}$, where σ_R is the total reaction cross section, is listed in the last column of Table I (see also Fig. 2).

The importance of having reaction cross section measurements for determining optical model potential parameters at least under some conditions has recently been shown by Olkowsky[12] in the optical model analysis of 10 MeV proton elastic scattering data on Cu. The same situation apparently holds



MU-27142

Fig. 2. Proton non-elastic cross sections $\sigma_R - \sigma_{CE}$ for 22.4 MeV deuterons plotted against the two-thirds power of the atomic mass, A.

for the deuteron optical potential. Halbert et al[13] have obtained striking fits to the comprehensive elastic scattering data at 11.8 MeV[14]. They obtain 2051 mb and 2217 mb for the predicted reaction cross section for Sn in two analyses[15] of 11.8 MeV deuteron elastic scattering data[14]. The measured value at 22.4 MeV for tin is 1563 ± 117 mb (see Table I and Figure 2). The theoretical values for Ni at 11.8 MeV, 1360 mb and 1396 mb, and the measured value for Ni, 1491 ± 63 mb, at 22.4 MeV are in better agreement. It should be noted that the reaction cross sections at 11.8 MeV will be lower than at 22.4 MeV due to coulomb barrier effects. Elastic scattering data by itself even when very comprehensive and with small experimental error is apparently not sufficient to predict the correct value of the reaction cross section in this case also. Conversely the experimental values of the reaction cross section are apparently necessary data for optical model analyses.

REFERENCES

1. C. J. Mullin and E. Guth, Phys. Rev. 82, 141 (1951).
2. E. W. Hamburger, B. L. Cohen and R. E. Price, Phys. Rev. 121, 1143 (1961).
3. R. Glauber, Phys. Rev. 99, 1515 (1955).
4. C. E. Porter, Phys. Rev. 99, 1400 (155).
5. B. D. Wilkins and G. Igo, submitted to The Physical Review.
6. F. A. Aschenbrenner, Phys. Rev. 98, 657 (1955).
7. R. A. Peck and J. Lowe, Phys. Rev. 114, 847 (1959).
8. J. L. Yntema and B. Zeidman, Phys. Rev. 113, 261 (1959).
9. J L. Yntema, Phys. Rev. 113, 261 (1959).
10. E. W. Hamburger, Phys. Rev. 123, 619 (1961).
11. R. G. Summers-Gill, Phys. Rev. 109, 1591 (1958).
12. J. Olkowsky (Centre d'Études Nucléaires Saclay, France), private communication.
13. E. C. Halbert, R. H. Bassel and G. R. Satchler, Bull. Am. Phys. Soc. Series II, Volume 7, No. 4 (1962).
14. G. Igo, W. Lorenz, and U. Schmidt-Rohr, Phys. Rev. 124, 832 (1961).
15. E. C. Halbert (Oak Ridge National Laboratory, Oak Ridge, Tennessee), private communication.