Revised Calculations on the Photodisintegration of the Deuteron*

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A numerical error which affected results in two of the approximations reported on previously is taken into account. Revised values of coefficients for formulas and graphs illustrating typical effects of the revision are supplied. The disagreement with experiment at the smaller proton angles and higher energies is accentuated while agreement with experiment at the lower energies and larger as well as smaller angles is, on the whole, improved and is practically unaffected at the lower energies and higher angles.

In a previous publication[1] by some of the present authors, the values of the differential cross section for the $d(\gamma,n)p$ reaction and of the expected polarization of the ejected protons have been given. In the course of an extension of the work which is in progress by means of a digital machine program, it was ascertained that the combination $\mu_p+\mu_n-\frac{1}{2}$ which enters Eq. (4.1) of the paper quoted was used in the computations as a number having the value $\mu_p+\mu_n+\frac{1}{2}$. This numerical mistake does not affect the results in approximations A, B, C of the paper. It matters, however, for approximations D and E since the erroneous number enters as a coefficient in the important cross product terms of matrix elements of $M1$ transitions to triplet states. Corrected values of quantities in Tables VIII-XI of reference 1 are listed below in Tables I-IV, respectively. The notation of reference 1 is used.

The effect of the revision is to decrease the difference between the values of the differential cross section in approximations D and C by a factor of roughly 3.6 leaving the difference between E and D nearly unchanged. Typical revised results are shown in Figs. 1-4 which correspond, respectively, to Figs. 3, 4, 5, and 7 of reference 1. According to the first of these at gamma

Table I. Angular distribution parameters in microbarns/sterad for protons in approximation D. Suffixes 1 and 2 correspond to potentials I and II.

E_γ (Mev)	a_1	b_1	c_1	f_1	a_2	b_2	c_2	f_2
22.2	5.23	51.7	0.410	50.2	4.83	52.5	0.372	51.2
32.2	5.52	29.1	0.508	27.5	5.26	29.4	0.474	27.8
62.2	5.36	7.60	0.560	5.84	5.33	7.47	0.534	5.82
102.2	4.06	2.55	0.449	1.02	3.98	2.54	0.423	1.17
152.2	2.83	1.21	0.332	0.060	2.65	1.17	0.296	0.217
177.2	2.41	1.16	0.299	0.185	2.26	1.06	0.265	0.267

Table II. Polarization parameters in microbarns/sr for protons in approximation D. Suffixes 1 and 2 correspond to potentials I and II.

E_γ(Mev)	A_1	B_1	E_1	F_1	G_1	A_2	B_2	E_2	F_2	G_2
22.2	−4.45	5.18	−0.908	5.31	−3.10	−4.36	5.12	−1.01	5.23	−2.98
32.2	−2.87	4.81	0.564	4.92	−1.48	−2.80	4.74	0.489	4.84	−1.38
62.2	−1.44	2.82	1.49	2.90	−0.416	−1.39	2.79	1.45	2.87	−0.387
102.2	−0.925	1.57	1.41	1.63	−0.349	−0.862	1.54	1.33	1.61	−0.354
152.2	−0.663	0.908	1.11	0.973	−0.387	−0.581	0.853	0.996	0.925	−0.382
177.2	−0.567	0.779	0.948	0.846	−0.410	−0.497	0.715	0.843	0.784	−0.387

Table III. Angular distribution parameters and total cross section for protons and neutrons in approximation E. The parameters are in microbarns/sr and σ_T is in microbarns. Suffixes 1 and 2 correspond to potentials I and II.

E_γ (Mev)	a_1	b_1	c_1	d_1	e_1	f_1	$\sigma_T(1)$	a_2	b_2	c_2	d_2	e_2	f_2	$\sigma_T(2)$
22.2	5.26	51.6	0.844	15.5	1.16	50.2	500	4.86	52.5	0.763	15.9	1.00	51.1	503
32.2	5.57	29.1	1.04	10.9	1.00	27.5	315	5.30	29.3	0.939	11.0	1.04	27.7	314
62.2	5.42	7.54	1.05	4.41	0.67	5.83	132	5.38	7.42	1.01	4.20	0.62	5.81	131
102.2	4.11	2.50	0.796	2.01	0.401	1.01	73.3	4.02	2.51	0.812	1.77	0.33	1.16	72.1
152.2	2.87	1.18	0.616	1.02	0.219	0.059	46.3	2.68	1.15	0.631	0.82	0.17	0.22	43.6
177.2	2.45	1.13	0.582	0.876	0.175	0.185	40.6	2.29	1.04	0.584	0.70	0.14	0.27	37.8

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[1] M. L. Rustgi, W. Zernik, G. Breit, and D. J. Andrews, Phys. Rev. **120**, 1881 (1960).

ray energies of 62.2 and 102.2 Mev, the agreement with experiment is not worsened by the change. Revision of Fig. 2 of reference 1 gives a slightly better agreement between approximation E and experiment than previously at 22.2 and 32.2 Mev for $\theta_{\mathrm{c.m.}}<90°$ and perhaps a slightly worse one for $\theta_{\mathrm{c.m.}}>90°$. At these low energies approximation D is almost indistinguishable from C. Figure 2 of the present note is a revision of Fig. 4 of reference 1 and shows for $\theta_{\mathrm{c.m.}}<90°$ a definitely worse agreement with experiment than previously for both D and E. For $\theta_{\mathrm{c.m.}}>90°$, approximation E shows no systematic deviation from experiment at 152.2 Mev and is somewhat better in this respect than Fig. 4 of reference 1. At 177.2 Mev the revision also improves the agreement of approximation E with experiment for $\theta_{\mathrm{c.m.}}>90°$.

Figure 3 shows proton polarization and is a revision of previous Fig. 5. As for the cross section, the difference between C and D is quite small in the revised calcu-

TABLE IV. Polarization parameters in microbarns/sr for protons and neutrons in approximation E. Suffixes 1 and 2 correspond to potentials I and II.

E_γ (Mev)	22.2	32.2	62.2	102.2	152.2	177.2
$A_1(p)$	−4.50	−2.90	−1.52	−1.05	−0.801	−0.715
$A_1(n)$	−4.87	−3.08	−1.29	−0.657	−0.433	−0.350
$B_1(p)$	4.78	4.61	2.51	1.47	0.770	0.549
$B_1(n)$	5.81	5.17	2.92	1.62	0.985	0.868
$C_1(p)$	0.798	0.835	0.899	0.776	0.596	0.552
$C_1(n)$	−0.798	−0.835	−0.899	−0.776	−0.596	−0.552
$D_1(p)$	0	0	0	0.06	0.09	0.09
$D_1(n)$	0	0	0	0.06	0.09	0.09
$E_1(p)$	−1.01	0.429	1.27	1.20	0.934	0.783
$E_1(n)$	−1.45	0.228	1.47	1.46	1.13	0.961
$F_1(p)$	5.00	4.73	2.56	1.60	0.987	0.777
$F_1(n)$	5.60	5.04	2.86	1.49	0.800	0.672
$G_1(p)$	−3.11	−1.51	−0.438	−0.326	−0.338	−0.356
$G_1(n)$	−3.82	−2.24	−1.01	−0.804	−0.631	−0.592
$H_1(p)$	−0.598	−0.414	−0.228	−0.205	−0.199	−0.188
$H_1(n)$	0.661	0.519	0.318	0.268	0.225	0.207
$L_1(p)$	5.31	4.93	2.90	1.58	0.890	0.753
$L_1(n)$	5.18	4.80	2.82	1.62	0.988	0.863
$M_1(p)$	−0.266	1.28	2.14	1.95	1.53	1.34
$M_1(n)$	−2.19	−0.594	0.627	0.707	0.540	0.408
$N_1(p)$	−0.335	−0.256	−0.070	0.071	0.181	0.199
$N_1(n)$	0.408	0.226	0.047	−0.069	−0.105	−0.110
$A_2(p)$	−4.48	−2.91	−1.54	−1.05	−0.748	−0.654
$A_2(n)$	−4.67	−2.88	−1.13	−0.528	−0.346	−0.286
$B_2(p)$	4.71	4.53	2.71	1.38	0.669	0.538
$B_2(n)$	5.68	5.07	2.88	1.63	0.984	0.857
$C_2(p)$	0.92	1.0	0.98	0.81	0.54	0.44
$C_2(n)$	−0.92	−1.0	−0.98	−0.81	−0.54	−0.44
$D_2(p)$	0	0	0	0.10	0.09	0.08
$D_2(n)$	0	0	0	0.10	0.09	0.08
$E_2(p)$	−1.20	0.301	1.18	1.05	0.788	0.663
$E_2(n)$	−1.36	0.277	1.55	1.47	1.07	0.888
$F_2(p)$	4.88	4.65	2.84	1.57	0.949	0.818
$F_2(n)$	5.54	4.99	2.89	1.44	0.739	0.603
$G_2(p)$	−2.97	−1.39	−0.384	−0.303	−0.314	−0.320
$G_2(n)$	−3.67	−2.12	−1.05	−0.790	−0.604	−0.557
$H_2(p)$	−0.550	−0.383	−0.193	−0.215	−0.253	−0.271
$H_2(n)$	0.628	0.472	0.279	0.271	0.272	0.277
$L_2(p)$	5.23	4.85	2.85	1.53	0.814	0.668
$L_2(n)$	5.12	4.74	2.83	1.63	0.964	0.827
$M_2(p)$	−0.287	1.25	2.12	1.85	1.33	1.10
$M_2(n)$	−2.29	−0.657	0.611	0.671	0.528	0.448
$N_2(p)$	−0.320	−0.190	−0.030	0.165	0.212	0.231
$N_2(n)$	0.370	0.260	−0.010	−0.093	−0.142	−0.150

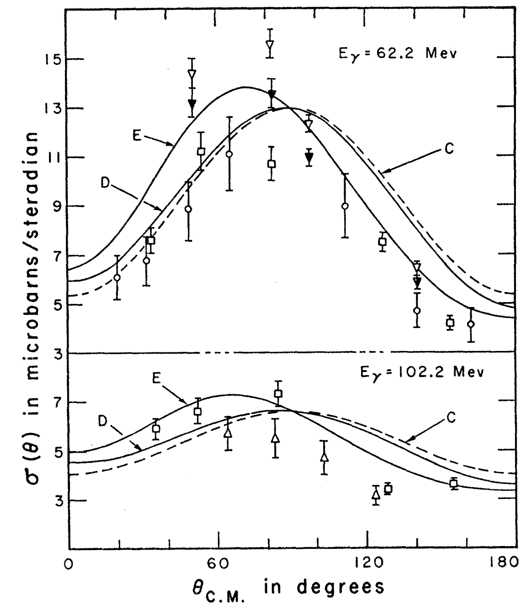

FIG. 1. Differential cross section for the $d(\gamma,n)p$ reaction with unpolarized gamma rays of energy 62.2 and 102.2 Mev in the laboratory system for potential I. The experimental points of various investigators are represented as follows: Circles for those of Allen at 66 Mev; squares for those of Whalin, Schriever, and Hanson at 65 and 105 Mev; triangles for those of Keck and Tollestrup at 105 Mev; open and solid inverted triangles for those of Galey at 60 and 65 Mev, respectively. [Some of the more recent results and references to earlier work are given by L. Allen, Jr., Phys. Rev. **98**, 705 (1955); J. C. Keck and A. V. Tollestrup, *ibid.* **101**, 360 (1956); E. A. Whalin, B. D. Schriever, and A. O. Hanson, *ibid.* **101**, 377 (1956); D. R. Dixon and K. C. Bandtel, *ibid.* **104**, 1730 (1956); C. A. Tatro, T. R. Palfrey, Jr., R. M. Whalley, and R. O. Haxby, *ibid.* **112**, 932 (1958); J. A. Galey, *ibid.* **117**, 763 (1960).]

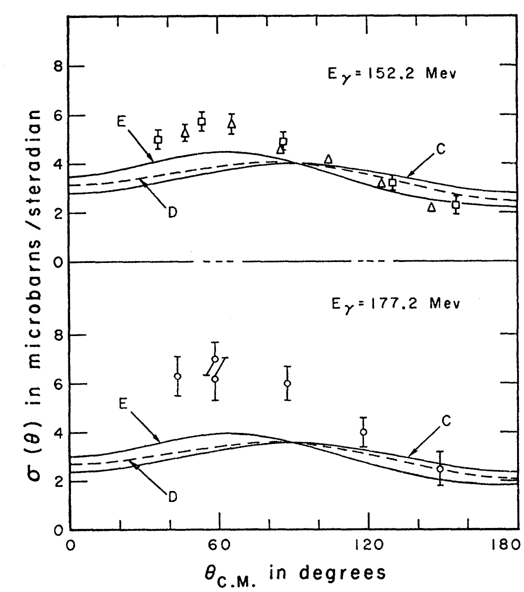

FIG. 2. Differential cross section for the $d(\gamma,n)p$ reaction with unpolarized gamma rays of energy 152.2 and 177.2 Mev in the laboratory system for potential I. The experimental points of the various investigators are represented as follows[3]: squares for those of Whalin, Schriever, and Hanson at 149 Mev; triangles for those of Keck and Tollestrup at 155 Mev; circles for those of Dixon and Bandtel at 182 Mev.

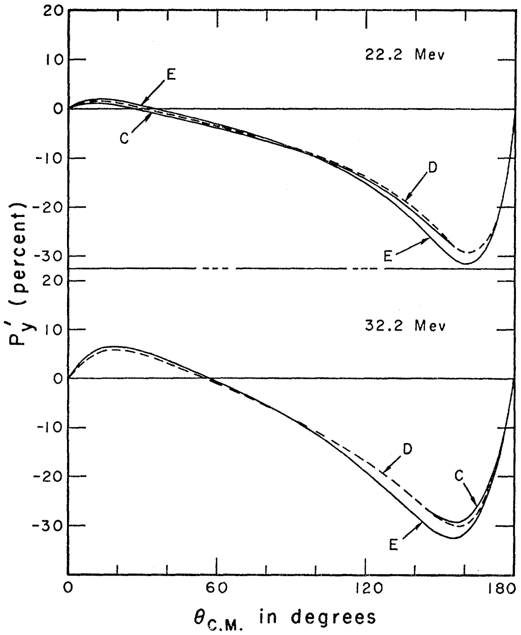

FIG. 3. Percentage polarization of protons from the $d(\gamma,n)p$ reaction with unpolarized gamma rays of energy 22.2 and 32.2 Mev in the laboratory system for potential I.

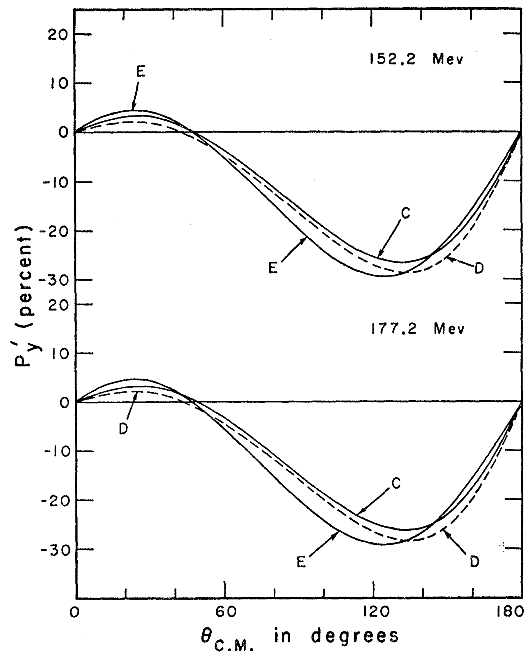

FIG. 4. Percentage polarization of protons from the $d(\gamma,n)p$ reaction with unpolarized gamma rays of energy 152.2 and 177.2 Mev in the laboratory system for potential I.

lations. In this case the revision has only a small effect. Figure 4 gives a revision of the previous Fig. 7 and shows proton polarization at gamma-ray energies of 152.2 and 177.2 Mev. The differences between approximations D, E, and C are again smaller than previously. While previously D showed no maximum at small angles it is now similar to C and E in this respect. The large-angle minimum of E gives a smaller P_y' than the corresponding minimum of D while previously the opposite was the case. The general features of the polarization graphs have not been affected, however.

The differences between results for potentials I and II in approximation E illustrated in Fig. 8 of reference 1 for cross section and in Fig. 9 of reference 1 for polarization are practically unaffected by the revision. As has been remarked in reference 1, the agreement with experiment then obtained, while not perfect, was better than one had reason to expect in view of uncertainties in the theory. The revised calculations improve the agreement of approximation E at high energies and larger angles. On the other hand, the disagreement at smaller angles becomes quite pronounced both at 152.2 and 177.2 Mev. In this respect the results appear to be more reasonable, the cases of approximate agreement for all angles being now confined to relatively small energies.

There are available revised versions of Figs. 2, 6, 8, and 9 of reference 1 which can be furnished on request. The revisions reported on apply also to an earlier publication,[2] the results of which have, however, been superseded by those in reference 1.

[2] W. Zernik, M. L. Rustgi, and G. Breit, Phys. Rev. **114**, 1358 (1959).