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Triton Elastic Scattering at 20 MeV*

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An optical-model analysis of the elastic scattering of 20-MeV tritons from 17 nuclides, from ^{40}Ca to ^{208}Pb, is presented. Average-parameter geometry sets as well as best-fit parameters are given. Two basic parameter families are considered, these being based on real-well radius parameters of 1.25 and 1.16 F, respectively. Average-geometry fits to all of the data indicate that the real-well depth is almost constant for all nuclides, whereas the imaginary depth shows a strong dependence on $(N-Z)/A$.

I. INTRODUCTION

THE availability of optical-model parameters for the elastic scattering of tritons has always been rather limited. This is primarily due to the unavailability of triton beams available from accelerators. However, the need and usefulness of such information is made obvious by the relatively large number of publications on direct reaction studies which involve the triton in one of the reaction channels. The (d, t) reaction for the study of neutron hole states has been employed for some time with relatively good success although the analysis of the data has suffered somewhat from the lack of triton optical-model information in the distorted-wave (DW) calculations. More recently the two-nucleon transfer reactions[1,2] (t, p) and (p, t) and the charge-exchange reaction[3] $(^3\text{He}, t)$ have also found considerable application.

The initial measurements of triton elastic scattering, at 12 MeV, were reported by Glover and Jones.[4] The availability of a triton beam at the Los Alamos three-stage Van de Graaff accelerator has produced the first elastic scattering results at 15 and 20 MeV which have been published by Hafele *et al.*[5] (HFB). Since these measurements, a number of direct-reaction experiments involving tritons incident on additional nuclei have been carried out. The interpretation of these data has also require knowledge of triton optical-model parameters and these have been obtained accordingly. Since the present elastic scattering data span a considerably larger range of nuclei than do those of HFB, it seems appropriate to report these newer results. In addition, the sensitivity of DW calculations for double stripping and double pickup to the choice of optical-model parameters has reduced to some extent the ambiguity in the parameters existing at the time of the HFB publication. Neglect of the contribution of a spin-orbit term as was done by HFB seems now to have theoretical justification. Recent calculations indicate that the strength of this term for tritons is expected to be no larger than one-third of that for free nucleons.[6,7]

The present paper concentrates its effort on two parameter families based on two values of the real radius. The first of these is the same family discussed in HFB, which uses a real-well radius parameter equal to the usual proton or neutron radius. Such a potential has proven to give useful results in DW calculations involving (t, d) reactions[8] and (t, t') reactions.[9] However, it is pointed out in both Refs. 8 and 9 that these particular reactions are insensitive to the choice of optical-model parameters used in the DW theory as long as they describe the observed elastic differential cross section. On the other hand, as mentioned previously, DW analysis of two-nucleon transfer reactions such as the (t, p) reaction is quite sensitive to which optical-model well is used. Studies in the Zr region[10] have indicated that a smaller real radius for the triton is required for the DW calculations to adequately describe the data. For this reason, the present paper also includes a systematic comparison to the data for a well of this smaller radius. Average parameters for these two wells as well as best fit parameters are presented.

II. EXPERIMENTAL TECHNIQUE

All of the data presented here were obtained using a 20-MeV beam of tritons from the Los Alamos three-stage Van de Graaff. The elastically scattered tritons were detected by means of ΔE-E counter telescope which consisted of a 500-μ surface-barrier silicon detec-

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[1] B. F. Bayman and N. M. Hintz, Phys. Rev. **172**, 1113 (1968), and references therein.

[2] E. R. Flynn, G. Igo, P. D. Barnes, and D. Kovar, Phys. Rev. Letters **22**, 142 (1969).

[3] J. J. Wesolowski, E. H. Schwarcz, P. G. Roos, and C. A. Ludemann, Phys. Rev. **169**, 878 (1968), and references therein.

[4] R. N. Glover and A. D. W. Jones, Nucl. Phys. **81**, 268 (1966).

[5] J. C. Hafele, E. R. Flynn, and A. G. Blair, Phys. Rev. **155**, 1238 (1967).

[6] L. R. Veeser, D. D. Armstrong, and P. W. Keaton, Jr., Bull. Am. Phys. Soc. **13**, 117 (1968).

[7] A. Y. Abul-Magd and M. El-Nadi, Progr. Theoret. Phys. (Kyoto) **35**, 798 (1966).

[8] G. Igo, P. D. Barnes, E. R. Flynn, and D. D. Armstrong, Phys. Rev. **177**, 1831 (1969).

[9] E. R. Flynn, A. G. Blair, and D. D. Armstrong, Phys. Rev. **170**, 1142 (1968).

[10] A. G. Blair, J. G. Beery, and E. R. Flynn (unpublished); J. G. Beery, Ph.D. thesis, University of New Mexico, 1969 (unpublished).

tor and 3-mm lithium-drifted silicon detector. Resolutions varied, depending upon experimental conditions, between 30 and 50 keV, with an average of 35 keV. An additional detector was used as a monitor to check on possible target or beam location change during the data-taking runs. The counter telescope could be located to an accuracy of ±0.05°, whereas the 0° position was determined to ±0.10°. The angular resolution of this telescope varied from 0.25° at the forward angles to 0.5° at the back angles.

To separate the reaction products from the elastically scattered tritons, particle identification was used. This was done by means of an on-line computer program which used the ΔE and E signals to identify the particle type. Four arrays of 512 channels each were reserved for various types of particles, with protons, deuterons, tritons, and α particles typically being stored. The gain of the system was set at about 18 keV per channel for the triton spectra. Analysis of the elastic data was generally done on line by a least-squares minimization routine which compares the experimental data to a skewed Gaussian with an exponential tail. A full description of the program which performs the particle identification and data analysis is given elsewhere.[11]

Except for the Zr isotopes, all of the targets used to obtain the forward-angle data were approximately 200 μg/cm^2 thick. They were generally obtained by vacuum evaporation and in some cases onto a carbon backing of 50 μg/cm^2. The Zr targets were obtained from Oak Ridge Isotopes Division of the Oak Ridge National Laboratory and were rolled metal of about 500 μg/cm^2. Thicker targets were used for some of the back-angle data. The isotopic purity for all targets was greater than 95% except ^{96}Zr, which was of 85% purity.

III. EXPERIMENTAL RESULTS

All of the elastic scattering data described here were taken along with other reaction data as described in Sec. II. Generally, these reaction data were desired from an angle between 12° and 21° out to 72°. Most of the data were taken in angular steps of 3°. To obtain a more meaningful determination of optical-model parameters, the elastic data were extended to larger angles, from 100° to 150° depending upon the target, and were also obtained for smaller angles into 10°. As discussed in HFB, the cross sections for forward angles are insensitive to optical-model parameters for medium to heavy nuclei. This is because the Coulomb terms are dominating the phase shifts which determine the scattering amplitude at small angles. Thus, by comparing the experimental results to the optical-model predictions at small angles, an absolute normalization may be obtained. This technique is usually accurate to ±5% in over-all accuracy and was used exclusively in this work to obtain absolute cross sections with on attempt made to measure target thickness or solid angle.

The data for the 17 isotopes are shown in Figs. 1–3. The present paper attempts to set forth several parameter sets which appear adequate for many DW calculations. However, undertakings by other authors could very well require other types of optical-model families which fit the data, and for this reason the data are available in tabular form from the authors.

IV. OPTICAL-MODEL CALCULATIONS

Optical-model parameters to describe the present data were obtained with the aid of a computer code due

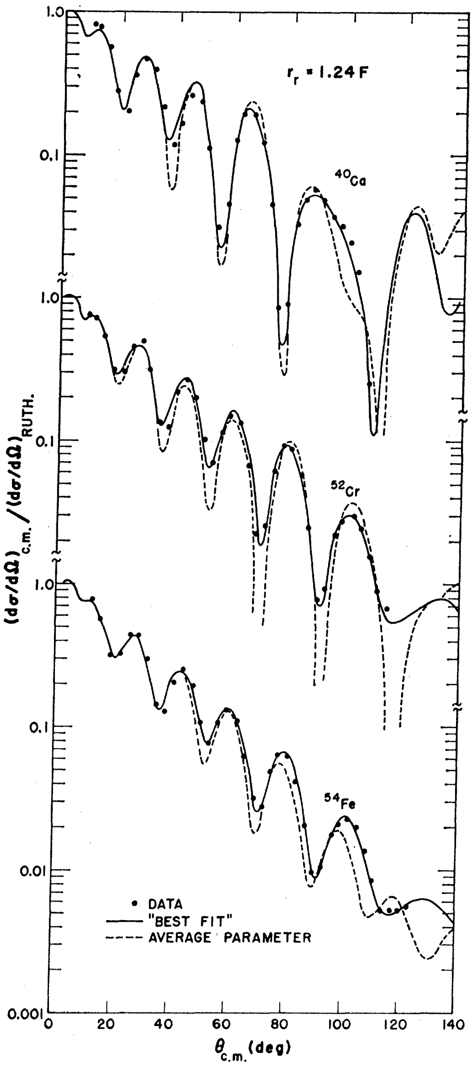

FIG. 1. Optical-model fits to the three lightest nuclei considered in this study. The real radius r_r was held fixed at 1.24 F for this analysis. The parameters for the best-fit cases are given in Table I and those for the average cases are given in Table II.

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[11] D. D. Armstrong, J. G. Beery, E. R. Flynn, W. S. Hall, P. W. Keaton, Jr., and M. P. Kellogg, Nucl. Instr. Methods 70, 69 (1969).

to Perey.[12] The potential form used was of the Woods-Saxon type

$$U=V_c(r)-[Vf(r)+iWg(r)],$$

where $f(r)$ and $g(r)$ are given by

$$f(r)=\left[1+\exp\left(\frac{r_rA^{1/3}-r}{a_r}\right)\right]^{-1}$$

and

$$g(r)=\left[1+\exp\left(\frac{r_iA^{1/3}-r}{a_i}\right)\right]^{-1}.$$

The Coulomb potential $V_c(r)$ is that of a uniformly charged sphere of radius $r_cA^{1/3}$. The Coulomb radius r_c has been found to have little effect on the predicted cross sections and was kept fixed at 1.25 F. The parameters to be adjusted to describe the experimental data are then the real and imaginary radii r_r and r_i, the real and imaginary diffuseness a_r and a_i, and the well depths V and W. Only the volume-type potentials shown above were used in the present analysis, and the possible effects of a surface imaginary term were not investigated. Also, no spin-orbit term is included for the reasons discussed previously.

Adjustment of parameters was done automatically by the program in order to minimize the value of (χ^2) defined by

$$\chi^2=\frac{1}{N}\sum_{i=1}^{N}\left(\frac{\sigma_{\text{theor}}(\theta_i)-\sigma_{\text{expt}}(\theta_i)}{\Delta\sigma_{\text{expt}}(\theta_i)}\right)^2,$$

where the σ's are the cross sections in mb/sr. N is the number of experimental points associated with the particular nuclide under study. In general, the $\Delta\sigma$'s were assigned a value of 5% of the cross section although the statistical errors were considerably less than this. The absolute values of the experimental cross sections were obtained by minimizing χ^2 for the forward-angle points as discussed previously.

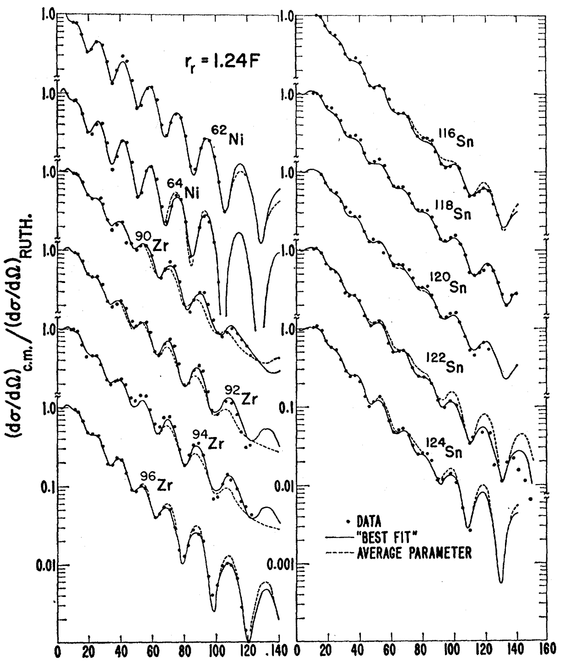

FIG. 2. Optical-model fits to the medium-weight nuclei including isotopes of Ni, Zr, and Sn. See also the caption to Fig. 1.

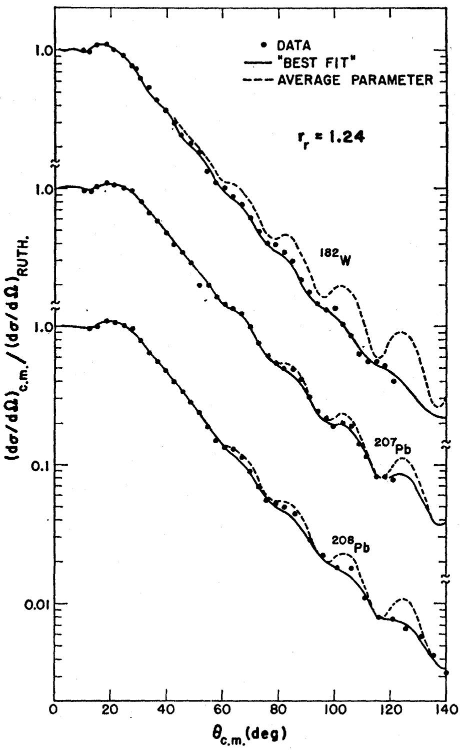

FIG. 3. Optical-model fits to ^{182}W, ^{207}Pb, and ^{208}Pb. See also the caption to Fig. 1.

V. OPTICAL-MODEL RESULTS

The HFB paper discussed the ambiguity which exists in potential families. In that work the real radius was chosen as 1.24 F to agree with previously published single-nucleon work[12,13] while the real potential depth was chosen as approximately three times that for a free nucleon. Success of optical-model parameters based on this work has led to a similar analysis of the larger amount of data presently available.

The procedure for fitting the data was as follows. The initial search used the parameters suggested in HFB, and all parameters (except r_r) were varied to obtain a best fit. After fitting all of the data, the geometrical parameters were averaged. A subsequent search was then carried out with these average parameters in which

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[12] F. G. Perey, Phys. Rev. 131, 745 (1963).

TABLE I. Best-fit parameters for $r_r = 1.24$ F. All parameters except r_r were varied to minimize χ^2. The starting values for the search were those suggested by Ref. 5.

Target	V (MeV)	W (MeV)	r_i (F)	a_r (F)	a_i (F)	χ^2
^{40}Ca	156.8	15.98	1.592	0.656	0.857	9.2
^{52}Cr	149.4	19.29	1.562	0.671	0.772	2.3
^{54}Fe	147.1	21.62	1.494	0.653	0.847	2.2
^{62}Ni	154.3	26.11	1.431	0.677	0.850	1.2
^{64}Ni	155.1	23.46	1.385	0.673	0.886	1.3
^{90}Zr	152.9	20.04	1.479	0.684	0.779	1.6
^{92}Zr	159.1	25.00	1.401	0.670	0.809	4.3
^{94}Zr	153.4	18.75	1.489	0.681	0.787	3.4
^{96}Zr	154.0	18.62	1.391	0.672	0.990	4.2
^{116}Sn	154.1	21.28	1.419	0.698	0.881	1.1
^{118}Sn	148.2	18.82	1.445	0.680	0.895	1.2
^{120}Sn	147.0	18.08	1.475	0.688	0.890	2.6
^{122}Sn	149.6	21.88	1.378	0.706	0.903	0.8
^{124}Sn	149.6	16.87	1.445	0.715	0.809	0.8
^{182}W	162.7	26.24	1.218	0.705	1.035	1.2
^{207}Pb	150.0	13.51	1.405	0.675	0.998	1.2
^{208}Pb	148.7	16.77	1.339	0.697	0.917	1.0

only V and W were allowed to vary. This search gave the V and W dependence for the average geometry set. This new set differs somewhat from that discussed in HFB owing to the increased amount of data now available. When all parameters (except r_r) were allowed to vary, they were seen to return to the values used in the averaging. This gave some assurance that all values used represented a good minimum in χ^2 space. The best-fit parameters for the $r_r = 1.24$-F family are given in Table I and the values of V and W for the average geometry parameters are given in Table II.

As mentioned previously, the DW calculations which are used to describe two-nucleon transfer reactions such as (t, p) and (p, t) are found to be quite sensitive to the optical-model parameters. When existing proton parameters were used in the above-mentioned reaction calculations,[12,13] it was found that a smaller triton radius was necessary to reproduce the trend of the experimental differential cross sections. The (t, p) reaction on the isotopes of Zr was best described by a triton radius parameter $r_r = 1.16$ F,[10] and on ^{207}Pb by $r_r = 1.14$ F.[14] These results were obtained after trying parameters which fit the elastic data and were based on choices of r_r varying from 1.0 to 1.25 F. Thus, an additional parameter family based on $r_r = 1.16$ F will be discussed

TABLE II. Average-geometry parameters for $r_r = 1.24$ F. The additional parameters held fixed were $r_i = 1.432$ F, $a_r = 0.685$ F, and $a_i = 0.870$ F.

Target	V (MeV)	W (MeV)	χ^2
^{40}Ca	156.4	18.43	31.5
^{52}Cr	150.7	18.85	37.4
^{54}Fe	142.4	26.77	21.2
^{62}Ni	148.8	26.52	2.1
^{64}Ni	152.1	22.28	5.8
^{90}Zr	151.1	24.06	9.1
^{92}Zr	154.4	22.90	10.3
^{94}Zr	150.8	22.69	13.0
^{96}Zr	153.9	17.76	9.8
^{116}Sn	155.9	18.96	3.8
^{118}Sn	148.7	19.70	1.3
^{120}Sn	148.9	19.93	3.0
^{122}Sn	149.9	17.16	12.1
^{124}Sn	150.5	15.52	5.2
^{182}W	162.4	13.44	65.9
^{207}Pb	150.3	11.99	3.7
^{208}Pb	149.8	12.02	11.7

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[13] L. Rosen, J. Beery, A. Goldhaber, and E. Auerbach, Ann. Phys. (N.Y.) **34**, 96 (1965).

[14] E. R. Flynn, G. Igo, P. D. Barnes, D. Kovar, and R. Broglia (unpublished).

here. This is not to imply that this is necessarily the correct choice and that the ambiguity in parameters is removed, however. The DW calculations are equally sensitive to the proton parameters used, and each phase shift in the reaction calculation is dependent upon the relative values assigned in the entrance and exit channels by the optical model. One would have to remove all uncertainties in the proton channel as well as in the DW form factor before more explicit statements could be made regarding the correctness of the triton-channel parameters.

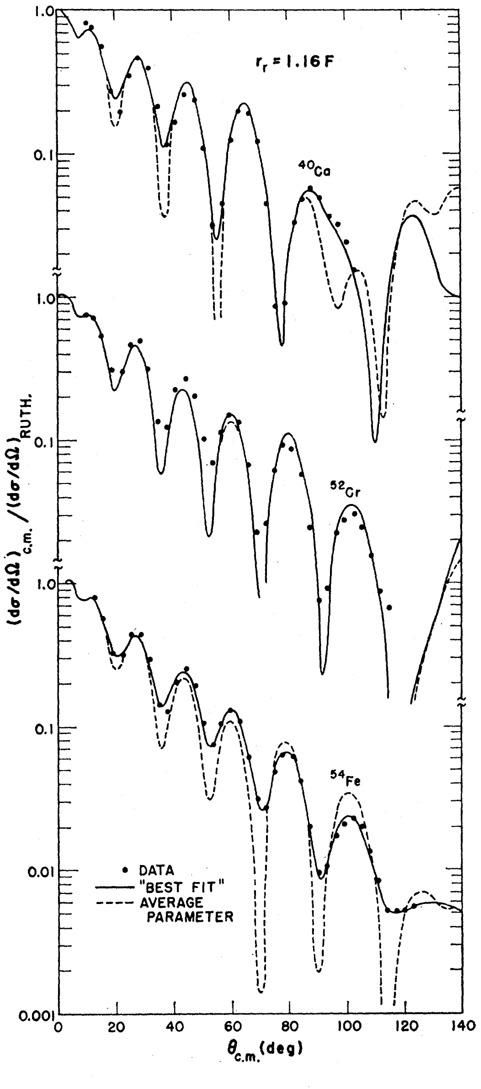

FIG. 4. Optical-model fits to the three lightest nuclei considered in this study. The real radius r_r was held fixed at 1.16 F for this analysis. The parameters for the best-fit cases are given in Table III and those for the average cases are given in Table IV.

The procedure in extracting the parameters for $r_r = 1.16$ F was the same as for the 1.24-F set. The best-

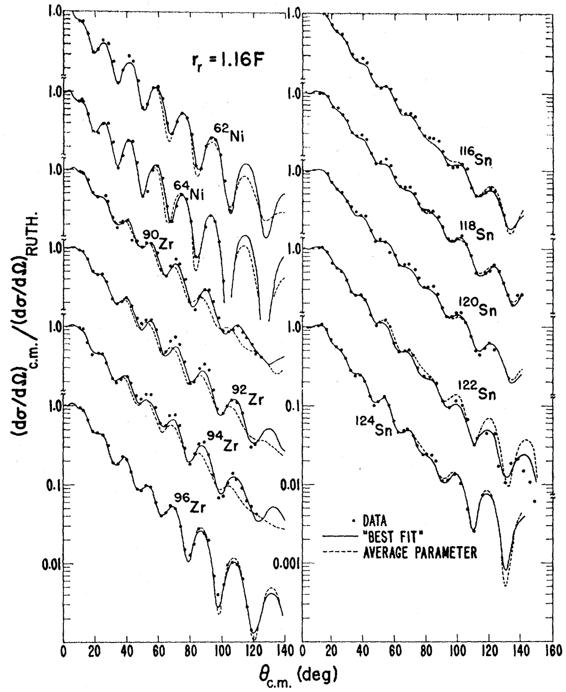

FIG. 5. Optical-model fits to the medium-weight nuclei including isotopes of Ni, Zr, and Sn. See also the caption to Fig. 4.

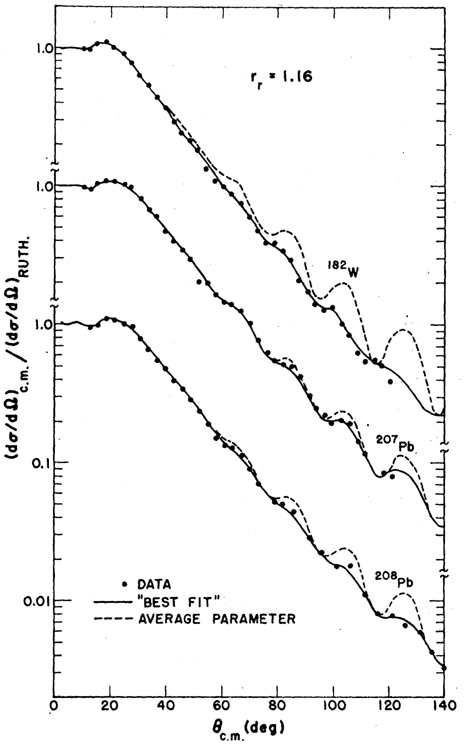

FIG. 6. Optical-model fits to ^{182}W, ^{207}Pb, and ^{208}Pb. See also the caption to Fig. 4.

TABLE III. Best-fit parameters for $r_r = 1.16$ F. All parameters except r_r were varied to minimize χ^2.

Target	V (MeV)	W (MeV)	r_i (F)	a_r (F)	a_i (F)	χ^2
^{40}Ca	172.7	14.8	1.650	0.700	0.806	6.4
^{52}Cr	164.8	22.8	1.575	0.760	0.758	36.6
^{54}Fe	163.3	20.2	1.550	0.705	0.794	1.6
^{62}Ni	169.7	22.8	1.510	0.732	0.796	1.3
^{64}Ni	170.5	20.5	1.488	0.732	0.810	1.3
^{90}Zr	170.2	18.8	1.520	0.739	0.751	1.9
^{92}Zr	177.4	22.3	1.460	0.726	0.778	5.6
^{94}Zr	171.0	17.0	1.542	0.732	0.774	4.2
^{96}Zr	171.3	16.8	1.481	0.735	0.885	4.3
^{116}Sn	170.1	18.8	1.489	0.759	0.839	1.5
^{118}Sn	164.5	16.7	1.510	0.741	0.843	1.2
^{120}Sn	163.5	16.1	1.531	0.745	0.847	2.6
^{122}Sn	165.4	18.7	1.458	0.771	0.846	1.0
^{124}Sn	165.1	15.0	1.510	0.780	0.782	1.1
^{182}W	183.1	21.6	1.332	0.760	0.994	1.0
^{207}Pb	165.8	11.3	1.510	0.761	0.876	1.0
^{208}Pb	165.5	13.9	1.442	0.769	0.864	0.8

fit parameters are given in Table III and the average-geometry set is given in Table IV. The optical-model fits to the data are shown in Figs. 4–6.

The three nuclei ^{40}Ca, ^{52}Cr, and ^{54}Fe are the lightest studied and, with the exception of ^{182}W, these represent the largest deviation from the average-geometry parameters. Tables II and IV indicate that large values of χ^2 are obtained for these three nuclei. Substantial improvement in the fits are obtained, however, when other parameters are freed. In particular, a larger imaginary radius than the average value is desirable for both the $r_r = 1.24$-F and $r_r = 1.16$-F families, as seen in Tables I and III. Figures 1 and 4 show the comparison of the data to the optical-model predictions for the two families and for both average and best-fit geometries. It is expected that these lighter nuclei would show deviation from the average trend. In addition to having fewer nucleons, ^{40}Ca has a closed shell of both protons and neutrons, and ^{52}Cr and ^{54}Fe both have a closed neutron shell. These structure effects undoubtedly cause deviation from the average behavior of nuclei. A number of additional triton optical-model sets for ^{40}Ca have been considered by Satchler *et al.*[15] and their effect on DW calculations for the $^{40}\mathrm{Ca}(t, d)^{41}\mathrm{Ca}$ reaction was discussed. Some sensitivity to these parameters was noted for this particular nucleus, in contrast to the results of heavier nuclei.

TABLE IV. Average-geometry parameters for $r_r = 1.16$ F. The additional parameters held fixed were $r_i = 1.498$ F, $a_r = 0.752$ F, and $a_i = 0.817$ F.

Target	V (MeV)	W (MeV)	χ^2
^{40}Ca	170.1	17.0	40.0
^{52}Cr	165.4	16.4	38.1
^{54}Fe	166.1	17.2	65.4
^{62}Ni	161.2	25.2	6.1
^{64}Ni	164.7	21.7	7.8
^{90}Zr	166.6	22.9	10.8
^{92}Zr	170.7	21.5	13.6
^{94}Zr	166.5	21.4	15.4
^{96}Zr	170.7	16.3	5.9
^{116}Sn	172.6	17.0	2.9
^{118}Sn	164.6	17.8	1.4
^{120}Sn	164.8	17.8	3.1
^{122}Sn	166.3	15.2	8.5
^{124}Sn	166.5	14.1	3.6
^{182}W	181.2	11.4	59.1
^{207}Pb	167.4	10.3	10.8
^{208}Pb	167.0	10.3	3.9

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[15] G. R. Satchler, D. D. Armstrong, A. G. Blair, E. R. Flynn, R. J. Philpott, and W. T. Pinkston (unpublished).

The medium-weight targets observed in this study are rather well fitted by the average-parameter sets, for either choice of real-well radius. Figures 2 and 5 illustrate the quality of fit to the medium-weight nuclei. The heaviest nuclei observed, the lead isotopes ^{207}Pb and ^{208}Pb, are also quite well described by the average-parameter set. The data for the heavier nuclei are shown in Figs. 3 and 6. There is, of course, less sensitivity to the parameters for the heavier nuclei since they show less diffractionlike structure. Data for the ^{122}Sn target extend somewhat farther in angle than the other isotopes. A slight difference in phase between prediction and measured value is noted in the region between 130° and 150°. Such an effect could be due to a spin-orbit interaction; however, no attempt to investigate this possibility was made.

The nucleus ^{182}W represents somewhat of a special case since it is the only known strongly deformed nucleus studied here. A low-lying 2^+ state at 0.100 MeV, which is part of a rotational band, has a very large inelastic cross section. In fact, for the present measurements this cross section was larger than the elastic cross section past 90°. This type of behavior was not observed for any of the other nuclides investigated. Nuclear deformation is expected to have a large effect on optical-model parameters which are, in general, based on spherical nuclei. Reference to Tables I and IV shows that poor fits are obtained for the average-parameter sets, whereas for the best-fit case the parameters obtained differ substantially from the other nuclei. The effect of using best-fit parameters versus an average set on the DW analysis of the ^{182}W$(t, d)^{183}$W reaction has been discussed elsewhere.[16] The over-all result is that extracted spectroscopic factors agree better with predicted values when optical-model parameters based on average trends of spherical nuclei are used rather than best-fit parameters to the experimentally measured cross section. A similar result was obtained for the ^{182}W$(d, p)^{183}$W reaction.[17] Proper calculations for stripping reactions on strongly deformed nuclei should probably be done using coupled-channel techniques which take into account the strongly excited rotational bands of which the ground state is only one member.

The average-geometry parameters have been summarized in Tables II and IV. Examination of these tables shows that the depth of the real potential is to first approximation independent of A. A least-squares fit substantiates this observation; it yields no functional dependence of V on A. Similarly, no functional dependence of V on $(N-Z)/A$ could be established. Thus, a constant value of V appears to describe the potential depth over the range of nuclides investigated. This result appears to be true for both $r_r = 1.24$ F and $r_r = 1.16$ F. The value of V for these two cases is 151.7±4.7 and 166.7±7.1 MeV, respectively.

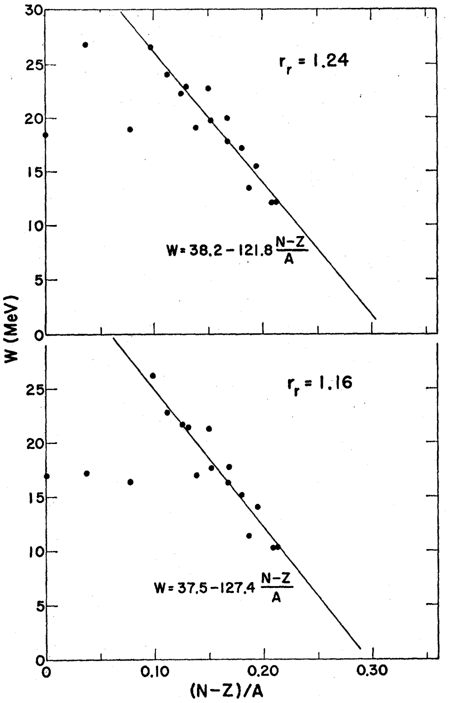

FIG. 7. Results of a least-squares fit of the relation $W = W_0 + W_1((N-Z)/A)$ to the values of W given in Tables II and IV for the two values of r_r considered. The results for ^{40}Ca, ^{52}Cr, and ^{54}Fe were not considered in this analysis.

In general, the form of the potential is expected to be given by $V = V_0 + V_1((N-Z)/A)$. Naive considerations would have suggested that V_1 for tritons would be about the same as for free nucleons, namely, 25 MeV. Indeed, comparison of ^{3}He ion to triton elastic scattering on ^{64}Ni and ^{90}Zr targets by Bassel *et al.*[18] indicated that an isospin term of 35 MeV best fit both sets of data. A term of this magnitude should have been discernible in the present analysis.

The lack of evidence of a real isospin potential can perhaps be attributed to the dominance of a strong isospin term appearing in the imaginary well. Figure 7 contains plots of W versus $(N-Z)/A$ for the two families. The line through the data is the result of a least-squares analysis using the relation $W = W_0 + W_1((N-Z)/A)$, but excluding the three lowest mass targets ^{40}Ca, ^{52}Cr, and ^{54}Fe. These lightest targets show considerable deviation from the isospin trend of the other data, and discussion of the isospin effect will be restricted to targets from the nickel isotopes upward. In fact, even tungsten shows no great deviation from this pattern. A similar dependence on the imaginary potential for protons was noted by Perey,[12] who found

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[16] E. R. Flynn, G. Igo, P. D. Barnes, and J. R. Erskine (unpublished).

[17] R. H. Siemssen and J. R. Erskine, Phys. Rev. Letters **19**, 90 (1967).

[18] R. H. Bassel, R. M. Drisko, and P. G. Roos, J. Phys. Soc. Japan Suppl. **24**, 347 (1968).

the sign of the isospin term relative to the constant term to be positive. There is some previous evidence for an isospin trend for mass-three projectiles. One piece of evidence is the difference in imaginary-radius parameters for triton scattering and ^{3}He ion scattering, which was pointed out in HFB; another is the work of Bassel *et al.*,[18] who extracted an isospin term for the imaginary potential in a similar fashion to the real potential discussed above. However, they used a derivative form for the isospin term (although the usual volume form for the constant term), and no quantitative comparison to their results can be made. The sign of their term for tritons is the same as that of the present results, with an opposite sign for the ^{3}He results. The present results indicate $W= 38.2\text{–}121.8\ (N-Z)/A$ MeV for $r_r=1.24$ F and $W= 37.5\text{–}127.4\ (N-Z)/A$ MeV for $r_r=1.16$ F.

Additional evidence for an isospin component in the imaginary term of the optical-model potential is found in the results of inelastic scattering of ^{3}He ions[19] and tritons.[9] The evidence is based on the observation that, for these projectiles, the form-factor term arising from the deformation of the imaginary well makes an important contribution to the cross section in a collective-model analysis of the data. Although the existing data have yet to be analyzed in a self-consistent fashion, examination of published results indicates that, in general, a deeper imaginary potential is required for ^{3}He-ion inelastic scattering than for triton inelastic scattering.

The isospin dependence of optical-model parameters has been discussed in detail by Satchler.[20] The evidence for such effects is quite definitive for protons but somewhat less so for neutrons. In a comprehensive study of proton optical-model parameters, Becchetti,[21] using a derivative form for the imaginary well, obtained an expression

$$W_D=(11.80-0.25E)+12((N-Z)/A)\text{MeV}.$$

Thus he found the isospin term to be of comparable magnitude to the other terms in this equation. Analysis of neutron data suggested an isospin potential of the same magnitude but of opposite sign. The present results agree with this analysis in the assignment of sign since the isotopic spin of the triton is the same as the neutron. Moreover, the triton isospin term appears to be approximately three times as large as the fixed depth rather than comparable to it.

VI. DISCUSSION AND CONCLUSIONS

Systematic optical-model fits to 17 nuclides have been made for triton elastic scattering at 20 MeV. Two parameter families have been obtained, differing only in the choice of the real-well radius. These radii were based on optical-model results for other particles and on results obtained in DW calculations. The quality of the fits are in general quite good, and, when an average of the geometrical parameters is taken, the over-all trend of the data also seems well reproduced. Perhaps most significantly, most of the data may also be described by a real-well depth of constant magnitude and an imaginary-well depth which is isospin-dependent. The exceptions to this are the lightest nuclei for which the fitted values of imaginary-well depth must be employed. Although all of the present work has been done at one energy, it is expected that there is only a small energy dependence of parameters. This is based on a comparison of ^{3}He elastic scattering results over a range of energies by Bassel.[22]

Many other forms and parameters of the optical-model potential could be obtained which would give results as good as those obtained here. The principal ambiguity occurs in the real potential and only two possibilities have been considered. Recently Jackson and Morgan[23] have investigated the behavior of the potential ambiguity for α particles. They compared the relation of Igo,[24] namely, $Ve^{R_0/a}\sim$const, to their results and found that this relation did not hold if the value of a differs very much from one potential to another. The present results also indicate that for the two families considered here the form of the ambiguity is more complicated than the Igo expression.

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