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SCATTERING OF 42-MeV (6.7-pJ) ALPHA PARTICLES FROM EVEN ISOTOPES OF CADMIUM

Supplement I - Absolute Cross Sections

by Norton Baron, Regis F. Leonard, and William M. Stewart

Lewis Research Center
Cleveland, Ohio

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ABSTRACT

Measurements have been performed that permit the determination of absolute cross sections for elastic and inelastic scattering of 42-MeV alpha particles from the even isotopes of cadmium. Previously reported measurements were unable to be converted to absolute cross sections because of the presence on the targets of a gold backing of unknown thickness. The thickness of the backing has been determined by measuring the yield of elastically scattered alpha particles from a gold foil of known thickness and comparing this yield with that observed from the gold backing during the cadmium experiment. Optical model and distorted-wave Born approximation calculations are carried out and compared with the absolute cross sections.

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SUMMARY

Auxiliary experiments have been performed to determine the amount of gold backing present on targets used in a previously reported experiment. These measurements make possible the determination of absolute cross sections for the scattering of 42-MeV alpha particles from isotopically enriched targets of cadmium 110, 112, 114, and 116.

The absolute elastic cross sections obtained have been analyzed using a four-parameter Woods-Saxon potential, and excellent fits have been obtained. Inelastic scattering has been analyzed using a distored-wave Born approximation (DWBA) calculation. The results of these calculations are in excellent agreement with the experimental data and with previously reported measurements of deformation parameters for one-phonon states.

INTRODUCTION

The present work was performed in order to obtain absolute cross sections based solely on experimental measurement for the scattering of 42-MeV alpha particles from the even isotopes of cadmium. In a previous report (ref. 1), absolute cross sections were inferred by adjusting their values in order to optimize the quality of fit obtainable in optical model calculations. This procedure was followed in the analysis of that data because of the presence of a gold backing of unknown thickness on the targets used in that work.

EXPERIMENTAL ARRANGEMENT

The experimental arrangement for the present work is identical to that described in reference 1. Alpha particles were scattered from a gold target of known thickness and detected in the same geometrical arrangement as was employed in reference 1. Comparison of the yield of this scattering with the yield of alpha particles scattered from the gold impurity in the cadmium targets then made possible an absolute determination of the amount of gold present in each of the cadmium targets. The thicknesses of the carbon backings were known so that it was then possible to obtain an absolute value for the thickness of the cadmium targets. In addition, it was possible to correct the cadmium elastic yields at forward angles where the gold elastic peak had interfered with the cadmium elastic peak.

EXPERIMENTAL RESULTS

The four cadmium targets employed in the work of reference 1 were determined to have the compositions and thicknesses given in table I. Thicknesses are quoted as a real density (mg/cm^2) and as the energy loss (keV) suffered by an 8.78 MeV alpha particle in passing through the target.

CROSS SECTIONS

The absolute cross sections for elastic and inelastic scattering of 42-MeV alpha particles from the even isotopes of cadmium are listed in tables II to V and are plotted in figure 1.

ANALYSIS OF ELASTIC AND INELASTIC SCATTERING

Both the elastic and inelastic scattering were analyzed in exactly the same way as reported in reference 1. The elastic data were fitted with a four-parameter Woods-Saxon potential, the parameters of which were automatically optimized by the computer code SCAT 4. The inelastic data were treated using the computer code DRC and the optical potentials which resulted from the fitting of the elastic scattering. Table VI lists the optical potentials that were obtained. Table VII lists the deformation parameters which resulted from fitting the inelastic data. The results of these calculations are shown with the data in figure 1.

CONCLUSIONS

Because the absolute magnitudes of the cross sections have been changed somewhat, the optical model parameters and nuclear deformation parameters reported herein are slightly different from those listed in reference 1. Fundamentally, however, the conclusions to be drawn from the earlier work are unchanged.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, September 13, 1968,
129-02-04-06-22.

REFERENCE

1. Baron, Norton; Leonard, Regis F.; and Stewart, William M.; Scattering of 42-MeV (6.7-pv) Alpha Particles From Even Isotopes of Cadmium. NASA TN D-4256, 1967.

TABLE I. - TARGET THICKNESS

Cadmium isotope	Cadmium thickness		Gold thickness	
	mg/cm^2	keV	mg/cm^2	keV
110	0.127	29.42	0.045	7.32
112	.312	72.0	.028	4.57
114	1.01	234	.024	3.8
116	.791	182	0	0

TABLE II. - DIFFERENTIAL CROSS SECTION FOR SCATTERING OF 42-MeV ALPHA PARTICLES FROM CADMIUM 110

(a) Elastic scattering

Center-of-mass scattering angle, θ_{cm}, deg	Differential cross section, $d\sigma/d\Omega$, fm^2/sr	Center-of-mass scattering angle, θ_{cm}, deg	Differential cross section, $d\sigma/d\Omega$, fm^2/sr
31.04	26.8±0.1	47.50	0.670±0.012
33.11	20.9±0.1	49.55	.647±0.012
35.17	12.1±0.1	51.60	.692±0.012
37.23	5.93±0.02	53.64	.481±0.011
39.28	3.66±0.02	55.69	.210±0.007
41.34	3.55±0.02	57.73	.087±0.005
43.40	2.90±0.02	59.77	.143±0.006
45.45	1.49±0.01	61.81	.155±0.004

(b) Inelastic scattering, 0.65 MeV

31.05	0.433±0.015	47.51	0.192±0.007
33.11	.186±0.009	49.56	.110±0.005
35.18	.334±0.011	51.61	.032±0.002
37.24	.539±0.009	53.66	.040±0.002
39.30	.368±0.009	55.70	.061±0.004
41.35	.123±0.005	57.74	.069±0.004
43.41	.068±0.005	59.78	.032±0.002
45.46	.176±0.005	61.82	.007±0.001

(c) Inelastic scattering, 1.48 MeV

31.06	0.088±0.009	47.53	0.010±0.001
33.13	.030±0.006	49.59	.031±0.002
35.19	.014±0.005	51.63	.022±0.002
37.25	.047±0.002	53.68	.010±0.001
39.31	.057±0.005	55.72	.006±0.001
41.37	.030±0.002	57.76	.010±0.001
43.42	.019±0.004	59.80	.0095±0.0015
45.48	.014±0.001	61.84	.0079±0.0014

(d) Inelastic scattering, 2.07 MeV

31.07	0.171±0.011	47.54	0.032±0.002
33.13	.320±0.009	49.59	.041±0.004
35.20	.200±0.009	51.64	.0516±0.0035
37.26	.103±0.004	53.69	.0470±0.0033
39.32	.066±0.005	55.73	.0179±0.0021
41.38	.138±0.005	57.78	.0198±0.0021
43.43	.144±0.006	59.82	.0108±0.0016
45.49	.079±0.004	61.85	.0274±0.0026

TABLE III. - DIFFERENTIAL CROSS SECTION FOR SCATTERING OF 42-MeV ALPHA PARTICLES FROM CADMIUM 112

(a) Elastic scattering

Center-of-mass scattering angle, θ_{cm}, deg	Differential cross section, $d\sigma/d\Omega$, fm^2/sr	Center-of-mass scattering angle, θ_{cm}, deg	Differential cross section, $d\sigma/d\Omega$, fm^2/sr
31.02	26.0±0.1	47.47	0.653±0.006
33.09	20.0±0.1	49.52	.755±0.008
35.15	11.3±0.1	51.57	.735±0.008
37.20	5.26±0.03	53.62	.462±0.005
39.26	3.04±0.03	55.66	.161±0.004
41.32	3.44±0.03	57.70	.010±0.003
43.37	2.64±0.01	59.74	.162±0.004
45.42	1.35±0.01	61.78	.165±0.003

(b) Inelastic scattering, 0.621 MeV

31.03	0.374±0.013	47.49	0.209±0.004
33.09	.160±0.009	49.53	.072±0.003
35.16	.320±0.009	51.58	.015. 0.001
37.21	.596±0.012	53.63	.042±0.003
39.27	.351±0.011	55.67	.087±0.003
41.33	.101±0.005	57.71	.070±0.003
43.38	.054±0.004	59.75	.0264±0.0016
45.43	.203±0.007	61.79	.0031±0.0008

(c) Inelastic scattering, 1.35 MeV

31.04	0.0393±0.0058	47.50	0.0186±0.0015
33.10	.0300±0.0054	49.55	.0201±0.0016
35.17	.0146±0.0042	51.60	.0105±0.0013
37.22	.0341±0.0040	53.64	.0058±0.0009
39.28	.0303±0.0040	55.69	.0050±0.0007
41.34	.0338±0.0031	57.73	.0080±0.0008
43.39	.0127±0.0024	59.77	.0125±0.0009
45.45	.0127±0.0023	61.81	.0090±0.0008

(d) Inelastic scattering, 1.98 MeV

31.05	0.154±0.008	47.51	0.0264±0.0017
33.11	.254±0.008	49.56	.0284±0.0019
35.18	.169±0.007	51.61	.0452±0.0023
37.24	.070±0.004	53.66	.0355±0.0021
39.29	.0334±0.0052	55.70	.0186±0.0012
41.35	.118±0.004	57.74	.0096±0.0009
43.41	.0945±0.0046	59.78	.0168±0.0012
45.46	.0540±0.0039	61.82	.0168±0.0013

TABLE IV.- DIFFERENTIAL CROSS SECTION FOR SCATTERING OF

42-MeV ALPHA PARTICLES FROM CADMIUM 114

(a) Elastic scattering

Center-of-mass scattering angle, θ_{cm}, deg	Differential cross section, $d\sigma/d\Omega$, fm^2/sr	Center-of-mass scattering angle, θ_{cm}, deg	Differential cross section, $d\sigma/d\Omega$, fm^2/sr
31.01	27.1±0	47.45	0.630±0.004
33.07	18.5±0	49.50	.678±0.004
35.13	11.3±0	51.54	.670±0.004
37.18	5.35±0.03	53.59	.374±0.003
39.24	3.72±0.02	55.63	.135±0.002
41.29	3.44±0.01	57.67	.0985±0.0017
43.35	2.54±0.01	59.71	.151±0.002
45.40	1.15±0.01	61.74	.138±0.002

(b) Inelastic scattering, 0.560 MeV

31.01	0.602±0.008	47.46	0.160±0.003
33.07	.194±0.003	49.51	.0526±0.0019
35.13	.436±0.006	51.55	.0180±0.0010
37.19	.568±0.007	53.60	.0426±0.0013
39.25	.370±0.005	55.64	.0770±0.0016
41.30	.106±0.003	57.68	.0570±0.0014
43.36	.105±0.003	59.72	.0183±0.0009
45.41	.208±0.004	61.76	.0026±0.0005

(c) Inelastic scattering, 1.23 MeV

31.02	0.0458±0.0038	47.47	0.0097±0.0008
33.08	.0197±0.0029	49.52	.0155±0.0009
35.14	.0231±0.0023	51.57	.0124±0.0008
37.20	.0298±0.0023	53.61	.0055±0.0005
39.26	.0460±0.0019	55.65	.0030±0.0004
41.31	.0309±0.0016	57.69	.0072±0.0005
43.37	.0207±0.0015	59.73	.0084±0.0006
45.42	.0070±0.0010	61.77	.0069±0.0005

(d) Inelastic scattering, 1.93 MeV

31.03	0.206±0.004	47.48	0.0119±0.0010
33.09	.229±0.005	49.53	.0170±0.0010
35.15	.1471±0.0035	51.58	.0341±0.0012
37.21	.0540±0.0023	53.63	.0251±0.0010
39.27	.0630±0.0022	55.67	.0111±0.0007
41.33	.0881±0.0026	57.71	.0057±0.0005
43.38	.0917±0.0026	59.75	.0093±0.0006
45.43	.0365±0.0018	61.79	.0105±0.0008

TABLE V. - DIFFERENTIAL CROSS SECTION FOR SCATTERING OF 42-MeV ALPHA PARTICLES FROM CADMIUM 116

(a) Elastic scattering

Center-of-mass scattering angle, θ_{cm}, deg	Differential cross section, $d\sigma/d\Omega$, fm^2/sr	Center-of-mass scattering angle, θ_{cm}, deg	Differential cross section, $d\sigma/d\Omega$ fm^2/sr
8.28	19000±21	45.37	0.929±0.010
10.34	9250±14	47.42	.620±0.005
12.41	4770±10	49.47	.693±0.005
14.48	2360±7.3	51.52	.572±0.004
16.55	1290±5.4	53.56	.241±0.003
18.61	670±3.9	55.60	.101±0.002
20.68	330±2.7	57.64	.107±0.002
22.74	199±2.1	59.70	.142±0.002
24.80	122.0±0.10	61.71	.0895±0.002
28.93	31.6±0.053	63.75	.0355±0.001
30.99	26.6±0.045	65.78	.0132±0.0005
33.05	21.2±0.038	67.81	.0228±0.0008
35.11	11.0±0.029	69.83	.0299±0.0008
37.16	4.52±0.020	71.86	.0227±0.0009
39.22	3.88±0.017	73.88	.00733±0.0003
41.27	3.31±0.019	75.90	.00255±0.0002
43.32	2.44±0.014	77.92	.0464±0.0002

(b) Inelastic scattering, 0.513 MeV

Center-of-mass scattering angle, θ_{cm}, deg	Differential cross section, $d\sigma/d\Omega$, fm^2/sr	Center-of-mass scattering angle, θ_{cm}, deg	Differential cross section, $d\sigma/d\Omega$ fm^2/sr
31.00	0.585±0.008	55.61	0.0730±0.0016
33.06	.131±0.004	57.65	.0365±0.0009
35.11	.478±0.006	59.69	.0149±0.0007
37.17	.593±0.008	61.72	.0096±0.0005
39.23	.322±0.005	63.76	.0254±0.0009
41.28	.0925±0.004	65.79	.0258±0.0008
43.33	.101±0.004	67.82	.0122±0.0006
45.38	.244±0.005	69.85	.0020±0.0003
47.43	.167±0.003	71.87	.0033±0.0004
49.48	.0535±0.003	73.89	.0086±0.0004
51.53	.0204±0.0009	75.91	.0099±0.0005
53.57	.0659±0.0017	77.93	.0053±0.0003

(c) Inelastic scattering, 1.21 MeV

28.94	0.0604±0.0024	55.63	0.00523±0.00046
31.00	.0836±0.0026	57.67	.00792±0.00043
33.06	.0260±0.0015	59.70	.00549±0.00044
35.12	.0327±0.0016	61.74	.00174±0.00021
37.18	.0618±0.0029	63.77	.00151±0.00022
39.24	.0466±0.0020	65.81	.00233±0.00023
41.29	.0295±0.0020	67.84	.00338±0.00033
43.34	.0137±0.0011	69.86	.00371±0.00031
45.40	.0151±0.0014	71.89	.00153±0.00019
47.45	.0206±0.0008	73.91	.00068±0.00010
49.49	.0190±0.0014	75.93	.00083±0.00014
51.54	.0117±0.0006	77.95	.00124±0.00013
53.58	.00410±0.00050		

(d) Inelastic scattering, 1.90 MeV

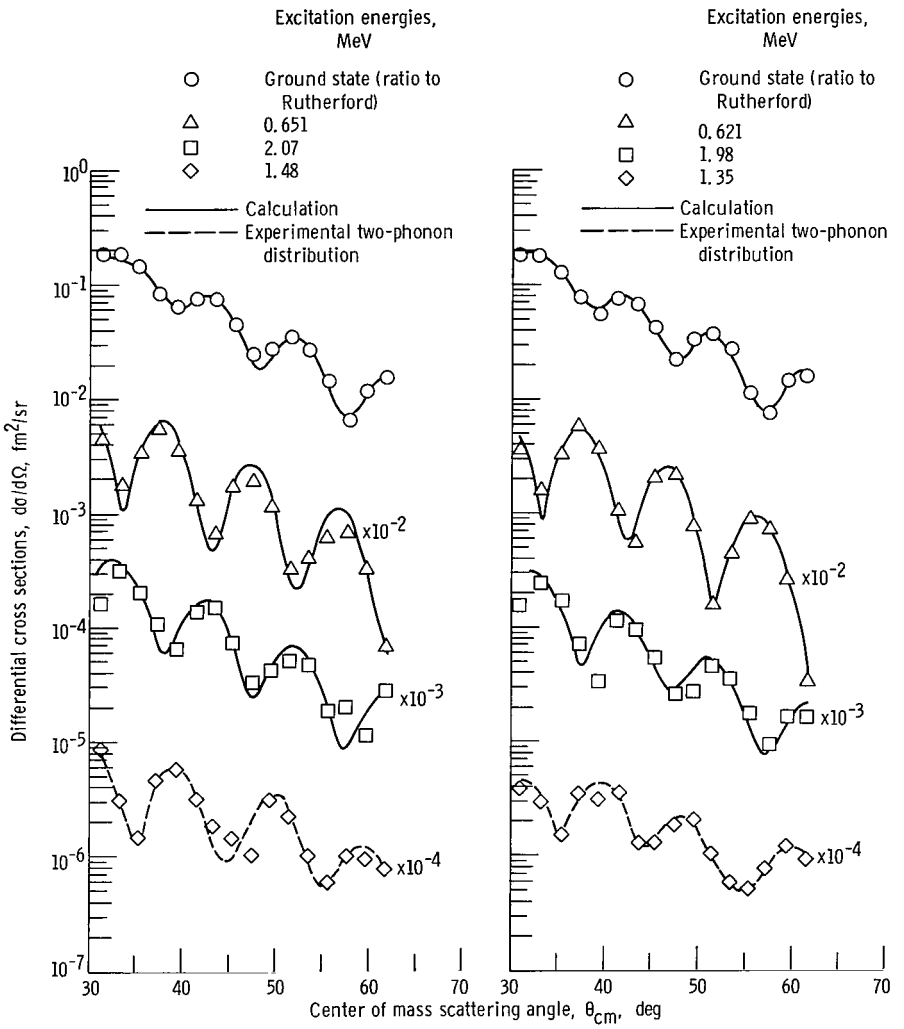
31.01	0.193±0.005	55.64	0.00725±0.0006
33.07	.175±0.005	57.68	.00590±0.00037
35.13	.142±0.004	59.72	.00945±0.0005
37.19	.0450±0.0023	61.76	.00965±0.0005
39.25	.0674±0.0024	63.79	.00551±0.0005
41.30	.0974±0.004	65.82	.00222±0.00023
43.36	.079±0.003	67.85	.00249±0.00029
45.41	.0344±0.0018	69.88	.00353±0.00028
47.46	.0186±0.0008	71.90	.00434±0.00032
49.51	.0238±0.0011	73.93	.00242±0.00018
51.55	.0318±0.0011	75.45	.00109±0.00015
53.60	.0206±0.0011	77.97	.00056±0.00009

TABLE VI. - ELASTIC SCATTERING ANALYSIS

Cadmium isotope	Strength of real part of nuclear optical potential, V, Mev	Strength of imaginary part of nuclear optical potential, W, Mev	Diffuseness parameter, a, fm	Nuclear radius constant, R_O, fm	Total reaction cross section, σ_R, fm^2	Goodness of fit, χ^2/N
110	44.19	20.07	0.6324	1.50	180.9	0.22
112	44.09	20.89	.6377	1.50	184.6	.58
114	39.34	21.26	.6587	1.50	188.3	.16
116	35.48	22.05	.7048	1.50	197.1	2.11

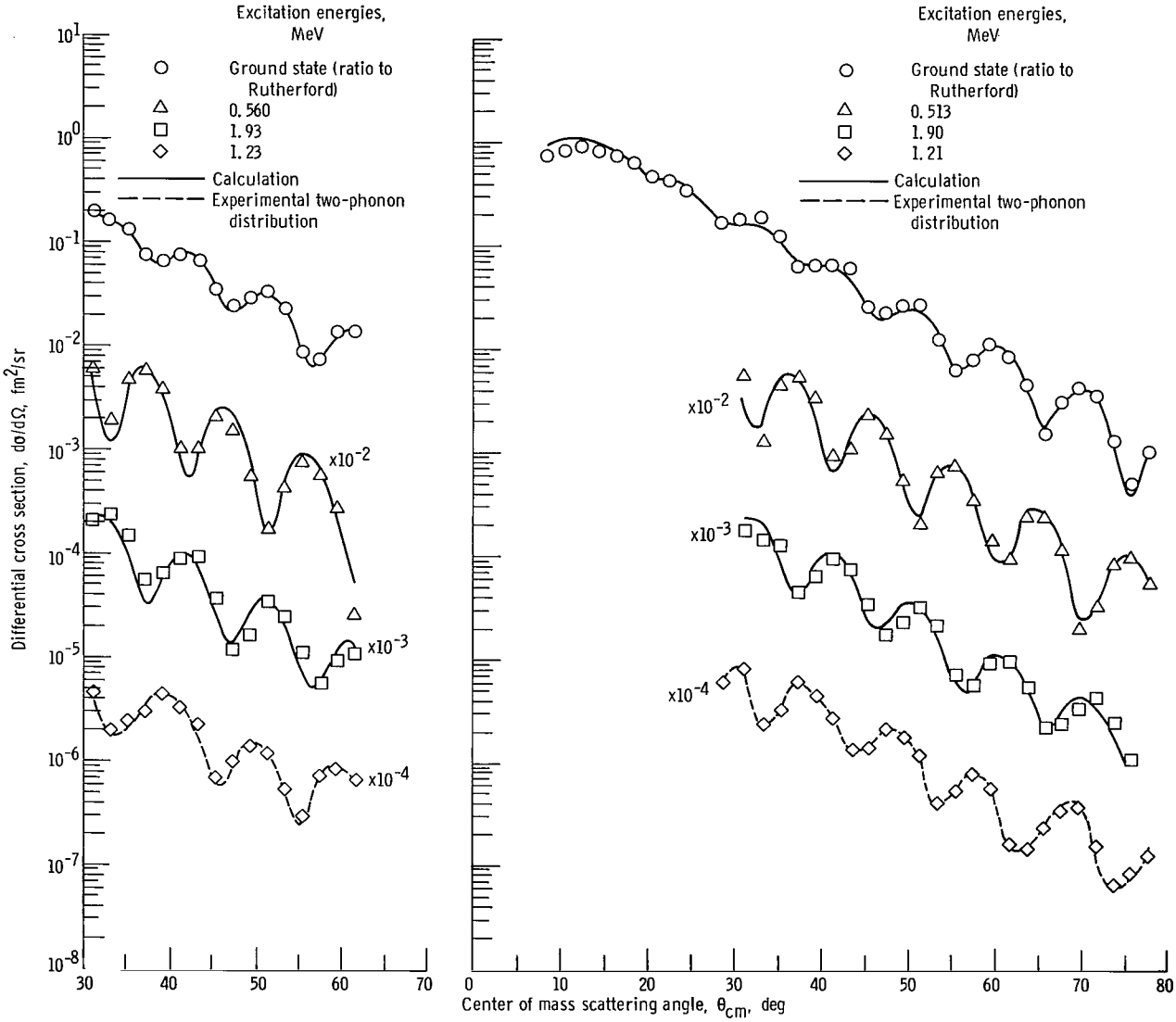
TABLE VII. - INELASTIC SCATTERING ANALYSIS

Cadmium isotope	Nuclear deformation parameters	
	β_2	β_3
110	0.20	0.18
112	.19	.15
114	.21	.14
116	.23	.15



(a) Cadmium 110. (b) Cadmium 112.

Figure 1. - Differential cross sections for elastic and inelastic scattering of 42-MeV alpha particles.



(c) Cadmium 114.

(d) Cadmium 116.

Figure 1. - Concluded.

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