Lawrence Berkeley National Laboratory

Recent Work

Title

ARGON ION REACTION STUDIES ON TANTALUM and GOLD NEAR COULOMB BARRIER ENERGIES

Permalink

<https://escholarship.org/uc/item/6s43f36q>

Author

Eggers, R.C.

Publication Date

1975-08-01

U 0 0 0 4 3 0 7 9 3 3

Submitted to Nuclear Physics A

LBL-4097
Preprint c.1

RECEIVED
LAWRENCE
BERKELEY LABORATORY

NOV 5 1975

LIBRARY AND
DOCUMENTATION

ARGON ION REACTION STUDIES ON
TANTALUM AND GOLD NEAR COULOMB BARRIER ENERGIES

R. C. Eggers, W. S. Ribbe and J. O. Rasmussen

August 1975

Prepared for the U. S. Energy Research and
Development Administration under Contract W-7405-ENG-48

For Reference

Not to be taken from this room

LBL-4097
c.1

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

ARGON ION REACTION STUDIES ON
TANTALUM AND GOLD NEAR COULOMB BARRIER ENERGIES*

R. C. Eggers,[†] W. S. Ribbe[‡] and J. O. Rasmussen[§]

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

and

Heavy Ion Accelerator Laboratory
Yale University
New Haven, Connecticut

ABSTRACT

Gold and tantalum targets were bombarded with a ^{40}Ar beam at 183 and 209 MeV, close to the Coulomb barrier height. Angular distributions of recoiling reaction products were measured by collecting on Al catcher foils. The radioactivity was counted after the irradiation by Ge(Li) detectors. One-neutron and one- and two-proton transfer products were prominent. Simple semiclassical transfer theory adequately fits the backward peaking angular distributions at or below the Coulomb barrier but fails at bombarding energies above the barrier. Yields of some products more than two mass numbers removed from reactants were observed in thicker targets at 235 MeV, and their significance is discussed.

* This work is reported in more detail in the doctoral thesis submitted by R.C.E. to Yale University. The research was supported by the U.S. Energy Research and Development Administration.

[†] Present address: Cyclotron Institute, Texas A&M University, College Station, Texas.

[‡] Present address: Stadt Rudolf-Virchow-Krankenhaus, Strahlungsabteilung, West Berlin.

[§] Present address: Department of Chemistry, Latimer Hall, University of California, Berkeley, California 94720.

0 0 0 0 4 3 0 7 9 5 5

-1-

NUCLEAR REACTIONS: ^{40}Ar on ^{181}Ta and ^{197}Au targets; measured $\sigma(\theta)$ one- and two-nucleon transfer products at 183 MeV. and 209 MeV; measured relative yield various products at 235 MeV. Catcher foils. Gamma counting of radioactivity.

INTRODUCTION

Few-nucleon transfer processes in heavy-ion collisions have long held a special interest for their promise to yield important nuclear structure information. Early impetus for the construction of the first heavy-ion linear accelerators came from the theoretical work of Breit and collaborators.¹ Their semiclassical tunneling theories showed the basic dependence of neutron transfer cross-sections on neutron separation energy, spectroscopic factors, and distance of closest approach in the heavy-ion trajectories. The proceedings of the first heavy-ion reaction conferences at Gatlinburg and at Asilomar present a great deal of work done on both theory and experiment at this early stage.^{2,3}

In the present work we have sought to find what new information we can gain from the simplest transfer reactions as we further increase the mass of the projectile. As the mass of the projectile increases, the wavelength decreases making more applicable the classical notions of the projectile sampling some small area on the surface of the target nucleus. With simple classical arguments, let us consider the difference between a spherical nucleus and a deformed nucleus, the latter having tips which extend significantly beyond the radius of an equivalent spherical nucleus. Transfer reactions proceed best for grazing trajectories just outside the surface of the nucleus. Since the deformed nucleus presents a variety of radii to the beam and the spherical nucleus presents only one, we would expect that the angular distributions of simple transfer products would be more sharply peaked at a classical grazing angle for spherical than for spheroidal collision partners.

The catcher foil technique is less elegant than modern dE/dx , E counter telescope measurements, which yield particle identification and

energy. However, present counter telescopes resolve adjacent charges but not adjacent-mass isotopes in the region we are studying. Thus, they cannot resolve the most significant transfer products near Coulomb threshold, namely, the one-neutron transfer products. Thus, the catcher foil technique provides complementary information.

RESULTS

To see what differences there might be between spherical and spheroidal targets we chose to run catcher foil experiments at the Berkeley Super Heavy Ion Accelerator. As targets we chose as spherical nuclei, gold, and as deformed, tantalum. These nuclei are as close in mass and charge as feasible, since the boundary between strongly deformed and spherical nuclei is not sharp in this region. We ran our experiment at energies close to the Coulomb barrier to make it possible to compare to theories involving nucleon tunneling with the projectile not deviating much from a Rutherford trajectory. We have made our measurements at 183 MeV, 209 MeV and 235 MeV lab energy. For the two lower energies we used a $400 \mu\text{g}/\text{cm}^2$ gold target and a $99 \mu\text{g}/\text{cm}^2$ tantalum target on $100 \mu\text{g}/\text{cm}^2$ carbon backing. At the 235 MeV energy we used a $5 \text{ mg}/\text{cm}^2$ gold target and a $10 \text{ mg}/\text{cm}^2$ tantalum target. From Tables of Northcliffe and Schilling⁴ we calculate negligible energy losses in the thin targets: $\sim 1.5 \text{ MeV}$ in the carbon backing and $\sim 0.6 \text{ MeV}$ in the thin Ta; $\sim 2.4 \text{ MeV}$ in the thin gold. The thick targets would cover energy ranges of 29 MeV for gold and 62 MeV for tantalum. The catcher foils were of .025 cm aluminum, thick enough to completely stop transfer products. It was not feasible to use stacked foils, so our data are necessarily integrated over all final kinetic energies and excitations of products.

Table 1 gives a list of the products which were identified and the properties used for calculation of cross sections. Table 2 gives a list of gamma-rays resulting from more than one product and not used. Table 3 gives a list of the differential reaction cross-sections by product and center of mass angle, as well as angle-integrated cross sections. We used two Ge(Li) detectors in this study with initial counting periods of 10 to 20 minutes followed by longer periods such that products of different half-lives could be counted. We searched for all possible products from our reactions, but expected them to be distributed close in Z and A to target and projectile at these near-barrier energies. For the highest energy runs (235 MeV) with thicker targets, we saw additional products, yields of which, relative to ^{41}Ar are given in Table 4. For the thick targets, reliable angular distributions and absolute cross sections could not be obtained.

One-Neutron Transfer Results and Discussion

Let us look at the evidence for differences (angle and energy integrated) between spherical and deformed nuclei. We have compared our ^{41}Ar angular distributions to theoretical calculations using the Semi-Classical Transfer Theory (SCTT), expressions of Alder, Morf, Pauli, and Trautmann.⁵

Their formulation goes beyond that of Breit and Ebel¹ notably in the inclusion of dependence on the angular momenta of the particular shell-model orbitals involved. For energies above the barrier Alder et al⁵ suggest that one may still be able to apply the theory by replacing the Rutherford cross section factor by an experimental or optical model elastic cross section.

Figure 1 shows excellent agreement at the lowest energy point, 183 MeV, for gold. There is only a slight dip in cross section at the most backward angle, indicating a slight absorption into other channels for the

nearly head-on collisions.

In Figure 2 for Ta at 183 MeV the agreement of SCIT theory and our data is not as good, in that the experimental angular distribution away from the peak does not drop as far as the theoretical. The same flattening trend is even more pronounced for the higher energy points.

Clearly the semi-classical transfer theory patched by the above-barrier elastic scattering cross section is not adequate for the angular distributions we measured. It is likely that much of the excess cross section away from the classical grazing angle arises from inelastic transfer, where the ^{41}Ar and its complement ^{196}Au are left in higher excited states.

It is interesting to compare with the back-angle Rutherford cross section (center-of-mass) for the 183 MeV ^{40}Ar on ^{197}Au , which is 113 mb/sr. Thus, the ^{41}Ar cross section of 2.6 mb/sr at back angle represents 2.3% conversion of the beam to this one product, a Breit-Ebel amplitude $|a(\infty)| = 0.15$. At 209 MeV the peak cross section at grazing is down to 0.5% of the Rutherford value.

It is reasonable to discuss the one-neutron transfer on spherical gold in terms of a few participating shell model states, for the Q window is probably small. For the head-on collision at 183 MeV we may estimate a collision time for transfer of about 8×10^{-22} sec, or a width of 0.9 MeV. (We calculate the collision time as the time spent within 2 Fm of the turning radius, 2 Fm being about the characteristic tunneling length of the bound neutron.) The Q value for ground state transfer is -2.0 MeV; hence, ground or low-lying states should dominate the transfer. For ^{40}Ar the neutron would be picked up into an $f_{7/2}$ orbital, and it might come from $p_{3/2}$ or $i_{13/2}$ orbitals in ^{197}Au (and, to the extent that pairing configuration mixing

was present, the $f_{5/2}$ orbitals). For the head-on trajectory by simple momentum matching arguments enumerated by Brink⁶ the matching neutron orbital angular momentum in Au would be greater than that in Ar by the ratio of their radii, thus making the tangential momenta of the transferred neutron match. For the $f_{7/2}$ Ar orbital the optimum $\ell_n = 3 \times (197/40)^{1/3} = 5.1$. In addition there is a spin selection rule that a $j = \ell + \frac{1}{2}$ orbital in one partner will match to a $j = \ell - \frac{1}{2}$ orbital in the other partner, since the direction of the orbital angular momentum reverses on transfer and the intrinsic spin direction does not. Thus, the ideal matching orbital in gold is the $h_{9/2}$, but the orbital would seem too deeply bound to contribute significantly, given the narrow Q window of ≈ 1 MeV and the Q value of -2.0 MeV. The $i_{13/2}$ orbital gives a reasonable ℓ match but violates the intrinsic spin rule. At 209 MeV energy the grazing orbital angular momentum is about 80. Hence, the ℓ match may shift by two units, making the $f_{5/2}$ orbital in gold favorable.

Our calculations with SCTT theory shows negligible difference in relative angular distributions for various orbitals $p_{3/2}$, $f_{5/2}$, $i_{13/2}$ in gold. That is, the angular distribution is dominated by the relationship between scattering angle and distance of closest approach for Rutherford trajectories.

The arguments for orbital momentum matching are somewhat more involved for a deformed target, such as tantalum, but by analogous arguments we would expect the lightly bound Nilsson orbitals with appreciable $h_{9/2}$ admixture to be the more effective for pick-up in nearly head-on collisions. Satisfying these criteria are the $7/2-[514]$ and $5/2-[512]$ orbitals. Both of these orbitals have wave functions peaking in the vicinity of 70° from the poles. Thus, only a particular zone of the surface and particular grazing radius is effective for producing ^{41}Ar , and the angular distribution is not necessarily less sharp than for a spherical nucleus.

The angular distributions for ^{39}Cl and ^{38}S can be seen from Table 3 to be rather similar to those for ^{41}Ar , but the statistics are generally so poor as to preclude detailed analysis.

Discussion of Proton Transfer and Multi-Nucleon Transfer

The proton transfer reaction $^{197}\text{Au}(^{40}\text{Ar}, ^{39}\text{Cl})^{198}\text{Hg}$ is endoergic with $Q = -5.44$ MeV. However, as Diamond et al⁷ pointed out, the effective driving energy for charge transfer reactions has an extra term equal to the change in Coulomb energy at grazing distance. For the above reaction this "Coulomb boost" is 6.63 MeV. Hence, the reaction favors leaving a total of ~ 1.2 MeV excitation in the final nuclei. The situation is very favorable for transfer of a $1s_{1/2}$ proton from ^{40}Ar into an empty $2s_{1/2}$ orbital in ^{197}Au . For tantalum the empty $2s_{1/2}$ proton lies a bit too high for optimum match.

Similar arguments apply for 2-proton transfer. The Q value for the gold target is -10.91 MeV, but the "Coulomb boost" is 13.48 MeV, favoring a total final excitation of ~ 2.6 MeV.

We note from Table 4 that one- and two-proton transfer is 2-3 times more favorable in gold than in tantalum, probably a consequence of the favorable Q and l match for gold.

Let us further examine Table 4 for the complementary thallium fragments from 2-proton transfer. We might expect the yield of ^{198}Tl to come from 2-proton transfer to ^{199}Tl states above the neutron binding energy, followed by neutron evaporation. However, there is an excess yield of these thallium products over the yield of ^{38}S , and ^{200}Tl is also seen. Hence, we conclude there must be alpha transfer ($Q = -8.25$ MeV) and perhaps ^3He transfer ($Q = -12.16$ MeV), partly followed by neutron evaporation. The "Coulomb boost" of ~ 13.5 MeV gives a positive driving force for both reactions.

Still it is difficult to account for the substantial yield of the ^{198}Tl isomers by a grazing transfer mechanism. There is no physical particle transfer forming these species, and values of Q plus Coulomb boost make unlikely the amount of excitation for so much neutron evaporation. Perhaps at this energy of 235 MeV, some 50 MeV (lab) above threshold, the collision partners can stick for a time, with nucleons diffusing in both directions.⁸

In Table 4 is shown a large excess of ^{196}Au yield over its complementary product ^{41}Ar , but this is easily understood. Any inelastic scattering processes exciting the target to between one- and two-neutron binding energy will give rise to ^{196}Au yield in excess of ^{41}Ar yield. The yield of the 12-isomer must be predominantly due to inelastic scattering followed by neutron emission, since the spectroscopic factors for its formation in transfer should be very small.

Finally, we take note of appreciable ^{43}K yields for both Ta and Au targets, although there are large probable errors attached to these yields. This product can arise either from triton ($1p, 2n$) transfer or from 3-neutron transfer followed by beta decay of ^{43}Ar . For the tantalum target we see the complementary 3-neutron transfer product ^{178}Ta . From the measured yields it would appear that both triton and 3-neutron transfer occur, though again it may be better here at more than 50 MeV over the barrier, to describe the process as diffusion of nucleons through a neck formed during a sticking period. The Coulomb boost works against the direct formation of ^{43}K , but the Q values are sufficiently positive to nearly compensate. Certainly from Table 4 it can be seen that there is no simple correlation of product yields with effective Q , such as Diamond et al⁷ and Artukh et al⁹ found. Evidently the 235 MeV results are in an intermediate region between the sub-barrier

region, where SCTT spectroscopic factors dominate, and a high energy region, where statistical factors govern.

ACKNOWLEDGMENTS

The authors would like to thank J. O. Liljezin for providing us with a table of gamma-rays by energy, the staff of the SuperHILAC in assisting with these experiments and Albert Ghiorso for his boundless enthusiasm. We also express appreciation to our colleagues at Yale Heavy Ion Accelerator Laboratory for the loan of the HP-4096 channel analyzer that made possible this work. We thank also Norman Glendenning for his program OPTIC with which we calculated optical model elastic scattering cross sections.

REFERENCES

1. G. Breit and M. E. Ebel, Phys. Rev. 103 (1956) 679.
2. Proceedings of the Second Conference on Reactions Between Complex Nuclei, ed. A. Zucker, F. T. Howard and E. C. Halbert (John Wiley & Sons, New York, 1960).
3. Proceedings of the Third Conference on Reactions Between Complex Nuclei, ed. A. Ghiorso, R. M. Diamond and H. E. Conzett (University of California Press, Berkeley, 1963).
4. L. C. Northcliffe and R. F. Schilling, Nucl. Data A7 (1970) 233.
5. K. Alder, R. Morf, M. Pauli and D. Trautmann, Nucl. Phys. A191 (1972) 399.
6. D. M. Brink, Phys. Lett. 40B (1972) 37; Cf. also P. J. A. Buttle and L. J. B. Goldfarb, Nucl. Phys. A176 (1971) 299; and A. R. Barnett, W. R. Phillips, P. J. A. Buttle and L. J. B. Goldfarb, Nucl. Phys. A176 (1971) 321.
7. R. M. Diamond, A. M. Poskanzer, F. S. Stephens, W. J. Swiatecki and D. Ward, Phys. Rev. Lett. 20 (1968) 802.
8. L. G. Moretto, R. P. Babinet, J. Galin and S. G. Thompson, Lawrence Berkeley Laboratory Report LBL-3444 (1974), submitted to Phys. Lett. B.
9. A. G. Artukh, V. V. Avdeichikov, J. Erö, G. F. Gridnev, V. L. Mikheev, V. V. Volkov and J. Wilczynski, Proceedings of the International Conference on the Properties of Nuclei far from the Region of Beta Stability; Leysin, Switzerland, Vol. 1, p. 47, CERN Report 70-30 (1970).

TABLE 1. Characteristics taken for observed radioactive products.

Product	Half-life (min.)	Energy (MeV)	Gamma Intensity (% of decay)
^{41}Ar	$109.6 \pm .4$	1.2936	99
^{39}Cl	$56.2 \pm .6$	1.2672	54
^{38}S	$169.6 \pm .7$	1.9417	84
^{43}K	1344.	.3729	86
		.6172	85
^{194}Au	2370.	.2936	11
		.3285	61
^{196}Au	8899.	.3329	23
		.3557	88
$^{196\text{m}}\text{Au}$	582.	.1478	42
		.1882	37
$^{198\text{g}}\text{Tl}$	318.	.6758	10
$^{198\text{m}}\text{Tl}$	112.	.5872	54
		.6367	59
^{199}Tl	444.	.2082	12
		.2473	9
		.4555	12
^{200}Tl	1566.	.3680	89
^{178}Ta	126.	.214	75
		.326	94
		.332	26
		.427	97

TABLE 2. Identified gamma-rays not used for cross section calculations.

Energy	Possible Source	Comments
.093 MeV	^{178}Ta or $^{180\text{m}}\text{Ta}$	These energies are too close (.09317 and .0933, respectively) to be resolved.
.412	^{198}Au , $^{198\text{g}}\text{Tl}$, and $^{198\text{m}}\text{Tl}$	Complex decay curves show mixture.
.426	^{196}Tl , $^{196\text{m}}\text{Tl}$, or ^{196}Au	Branching ratio between the first two is uncertain.

TABLE 3. Transfer reaction cross sections for argon-40 beam (mb/sr c.m.)

Target	Product	Lab Energy	6° - 15° 8° - 18°	15° - 45° 18° - 54°	45° - 75° 54° - 88°	75° - 105° 88° - 118°	105° - 135° 118° - 144°	135° - 165° 144° - 168°	165° - 174° 168° - 175°	Total (mb)
Ta	⁴¹ Ar	183 MeV	28 ± 2	0.42 ± 0.19	0.50 ± 0.17	1.50 ± 0.15	3.4 ± 0.4	1.50 ± 0.40	0 ± 3.96	18.6 ± 1.40
		209 MeV	26 ± 4	1.37 ± 0.30	10.3 ± 1.0	0.90 ± 0.20	0.53 ± 0.22	0 ± 1.01	0 ± 5.1	44.1 ± 3.78
	³⁹ Cl	183 MeV	12.4 ± 4.2	0 ± 0.38	0 ± 0.64	0.60 ± 0.30	3.08 ± 1.42	2.74 ± 0.54	0 ± 8.24	12.7 ± 4.18
		209 MeV	0 ± 5.30	0 ± 0.356	5.48 ± 1.18	.596 ± .274	0 ± 0.466	2.92 ± 1.16	0 ± 14.9	24.4 ± 4.77
	³⁸ S	183 MeV	0 ± 3.06	0 ± 0.314	0 ± 0.283	.258 ± .120	1.46 ± .386	1.30 ± .559	0 ± 7.6	5.68 ± 1.86
		209 MeV	0 ± 2.99	.181 ± .248	0 ± .757	0 ± .145	0 ± .292	0 ± .929	0 ± 7.63	0.89 ± 3.05
Au	⁴¹ Ar	183 MeV	0 ± 0.77	0 ± 0.70	.077 ± .052	0.40 ± 0.04	2.65 ± 0.32	2.77 ± 0.21	2.59 ± 1.25	11.3 ± 1.75
		209 MeV	1.64 ± 0.57	0.60 ± 0.20	4.0 ± 0.2	2.85 ± 0.20	1.3 ± 0.1	0.67 ± 0.15	0 ± 2.1	37.9 ± 1.1
	³⁹ Cl	183 MeV	5.54 ± 4.06	0 ± 0.106	0 ± 0.192	0 ± 0.082	1.26 ± 0.28	2.84 ± 0.26	9.12 ± 5.98	7.08 ± 1.23
		209 MeV	3.16 ± 1.28	0 ± .122	1.46 ± 0.20	1.90 ± 0.30	1.22 ± 0.32	.432 ± .154	0 ± 4.32	17.8 ± 1.53
	³⁸ S	183 MeV	1.88 ± 2.95	0 ± .097	0 ± .089	0 ± .043	0 ± .385	0.95 ± 0.19	0 ± 2.25	1.08 ± 1.02
		209 MeV	0 ± 1.06	0 ± .107	.718 ± .120	.472 ± .069	.282 ± .146	0 ± .194	1.47 ± 1.68	6.12 ± 0.70

All differential cross sections are in millibarns per steradian, center-of-mass system. Upper angular range in heading is laboratory system angles and lower range is for center-of-mass.

All total cross sections are missing any unmeasured cross section recoiling into the angular range 0-15° and 175-180° lab.

TABLE 4. Relative yield of various products at 235 MeV and reaction Q values.

Target	Product*	Yield Relative to ^{41}Ar as 100	Q (MeV)	Q ⁺ with Coul.boost
$^{181}_{73}\text{Ta}$	^{41}Ar	100	-2.0	
	^{39}Cl	20 ± 1	-5.51	+0.57
	^{38}S	7 ± 1	-11.7	+0.7
	^{43}K ($+^{43}\text{Ar}$)	122 ± 113	+5.41 (+1.586) [†]	-0.46
	^{178}Ta	45 ± 6	1.586	0
.....				
$^{197}_{79}\text{Au}$	^{41}Ar	100		
	^{39}Cl	61 ± 2	-5.44	+1.19
	^{38}S	16 ± 4	-10.91	+2.57
	^{43}K ($+^{43}\text{Ar}$)	25 ± 19	+5.09 (+0.483) [†]	-1.33
	$^{196}\text{Au}(2-)$	213 ± 49	-2.0	
	$^{196\text{m}}\text{Au}(12-)$	11 ± 5	-2.7	
	$^{198}\text{Tl}(2-)$	26 ± 3		
	$^{198\text{m}}\text{Tl}(7+)$	15 ± 1		
	^{199}Tl	26 ± 3	-10.91	+2.57
	^{200}Tl	18 ± 1	-12.16	+1.32

*Where isomeric pairs are observed, spin and parity are given in parentheses.

[†]Where mass decrements are not given in the Table of Isotopes,^a as for ^{43}Ar , we have used theoretical mass values from Myers and Swiatecki's 1965 tables.^b This situation occurs only for the observed ^{43}K product, which will be a sum of yields of 3-neutron transfer and triton (p+2n) transfer. The Q value for the former process is given in parentheses.

^aC. M. Lederer, J. M. Hollander and I. Perlman, "Table of Isotopes", (John Wiley & Sons, New York, 1968).

^bW. D. Myers and W. J. Swiatecki, "Nuclear Masses and Deformations", Lawrence Radiation Laboratory Report UCRL-11980 (1965).

FIGURE CAPTIONS

Fig. 1. Angular distribution of ^{41}Ar produced from the reaction of ^{40}Ar on ^{197}Au at 183 MeV (lab). The solid line is the SCTT theory⁴ with an elastic cross section taken from an optical model program with real and imaginary Woods-Saxon potential of radius constant 1.28 fm and diffuseness 0.4 fm. The potential depth is taken as 70 MeV for the real part and 15 MeV for the imaginary. Note that the theory fits the angular distribution rather well. The theoretical curve here is for the $f_{7/2}$ neutron orbital in argon and $p_{3/2}$ in gold, but the angular distribution is essentially the same for gold orbitals of other j values. The absolute theoretical cross section has been normalized upward by a factor of 8.0, but absolute cross sections depend sensitively on the radius constant used in the SCTT theory, here taken as 1.25 fm.

Fig. 2. Angular distribution of ^{41}Ar produced from the reaction of ^{40}Ar on ^{181}Ta at 183 MeV. The solid line is the SCTT theory⁴ with an elastic cross section calculated in the same manner as for Fig. 1, but with renormalization factor of 2.0 and $i_{13/2}$ neutron orbital. The most forward angle point is unreliable, since ^{40}Ar scattered into the catcher foil might transfer there.

Fig. 3. Angular distribution similar to Fig. 1, except for 209 MeV. Note that there is a marked disagreement between the theory and the experiment as to the width of the peak at the classical grazing angle. The theoretical curve has been renormalized upward by a factor of 8.4.

Fig. 4. This is a similar angular distribution to Fig. 2, except that the energy here is 209 MeV. The theoretical curve is normalized upward by a factor of 10. Note that there is again a marked disagreement between the theory and the experiment as to the width of the peaking at the classical grazing angle.

XBL743-2714

Fig. 1

XBL743-2711

Fig. 2

XBL 743-2712

Fig. 3

Fig. 4

LEGAL NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

TECHNICAL INFORMATION DIVISION
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720