Low-Lying Excited States of Ag^{108} and Ag^{110} Populated in Thermal-Neutron-Capture Reactions*

H. H. BOLOTIN AND A. I. NAMENSON†
Argonne National Laboratory, Argonne, Illinois
(Received 22 December 1966)

The thermal-neutron-capture γ-ray spectra following the reactions $Ag^{107}(n,\gamma)Ag^{108}$ and $Ag^{109}(n,\gamma)Ag^{110}$ were studied with the aid of a Ge(Li) detector operated in the singles and pair-spectrometer modes. The use of isotopically enriched targets led to unambiguous assignments of 33 primary transitions in Ag^{108} and 46 transitions issuing from the capture state in Ag^{110}. In each nuclide, these transitions were used to define the low-lying states to an accuracy of $\sim\pm1$ keV up to an excitation energy of $\sim$1300 keV. The observed strengths of the primary transitions are examined to determine the possible presence of systematic regularities of the type reported in the rare-earth rotational region. Comparisons are made between these data and previous (d,p) studies with a view toward establishment of the parity of the states populated in both reactions.

I. INTRODUCTION

SYSTEMATIC regularities reported in recent studies of the thermal-neutron-capture γ-ray spectra of some of the rare-earth rotational nuclides[1–4] have led to speculation that the s-wave neutron-capture process may not be wholely characterized by a purely statistical mechanism. The present study was undertaken to investigate any possible similar systematic effects which might be present in the spherical region.

The Ag isotopes were selected for study for several particular reasons. Silver has only two stable isotopes, both of which are available in $\sim$100% enrichments. Therefore, no ambiguities should exist in the isotopic identifications of the observed transitions. The two Ag isotopes are quite similar. Since both Ag^{107} and Ag^{109} have ground-state spins of $\frac{1}{2}^-$, s-wave capture leads only to initial states of spin 0^- and 1^-. The dipole γ rays from these capture states to low-lying states of the odd-odd product nuclides populate only states having spins of 0, 1, or 2. The available evidence[5] on the neighboring odd-A nuclides indicates that although the shell-model configurations that are expected to characterize the low-lying excited states are somewhat complex, these levels in Ag^{108} and Ag^{110} should be similar in their general features. Therefore, if regularities were to be observed in the primary transitions to these levels, these two similar nuclides could provide a means of comparing these effects in a systematic way.

Further interest in these nuclides stems from the expectation that the shell-model configurations characterizing the low-lying states in Ag^{108} and Ag^{110} would lead to (d,p) population of only the negative-parity states—the positive-parity levels close to the ground state are expected to arise from excited-proton configurations that (d,p) reactions do not populate or at most populate extremely weakly. Therefore, primary transitions from the negative-parity capture states to low-lying levels that are also seen in the (d,p) reaction would be expected to be $M1$. Since the average probability for primary $E1$ transitions to low-lying excited states is expected to be $\sim$10 times that for the corresponding $M1$ transitions,[6] these Ag isotopes provide a means of examining the ratio of the $E1$ to the $M1$ transition probability for many transitions in a single nuclide.

The results of the present experiment have established the position of 32 low-spin states in Ag^{108} and 45 similar states in Ag^{110} up to excitation energies of $\sim$1300 keV in each nuclide. These results are compared with existing (d,p) data[7] and with previous (n,γ) studies.[8]

II. EXPERIMENTAL PROCEDURE AND ANALYSIS

Metallic targets enriched[9] to 98.8% in Ag^{107} and 99.1% in Ag^{109} were employed. The samples were installed at the center of a tangential through-tube facility in the Argonne CP-5 reactor. In this facility, described elsewhere,[10] the thermal-neutron flux at the sample position was $\sim3\times10^{13}$ neutrons/cm^2 sec. In order to avoid as much contaminating background as

* Work performed under the auspices of the U. S. Atomic Energy Commission.
† Present address: Laboratory for Cosmic Ray Research, U. S. Naval Research Laboratory, Washington, D. C.
[1] A. I. Namenson and H. H. Bolotin, Phys. Rev. (to be published).
[2] M. J. Martin, J. A. Harvey, and G. G. Slaughter, Bull. Am. Phys. Soc. **11**, 336 (1966).
[3] R. K. Sheline, C. E. Watson, B. P. Maier, U. Gruber, H. R. Koch, O. W. B. Schult, H. T. Motz, E. T. Jurney, G. L. Struble, T. v. Egidy, Th. Elze, and E. Bieber, Phys. Rev. **143**, 857 (1966).
[4] H. T. Motz, E. T. Jurney, O. W. B. Schult, H. R. Koch, U. Gruber, B. P. Maier, H. Baader, G. R. Struble, J. Kern, R. K. Sheline, T. v. Egidy, Th. Elze, E. Bieber, and A. Backlin, Phys. Rev. (to be published).
[5] *Nuclear Data Sheets*, compiled by K. Way *et al.* (Printing and Publishing Office, National Academy of Sciences—National Research Council, Washington 25, D. C.), NRC 60-5-135, 60-2-47.
[6] G. A. Bartholomew, Ann. Rev. Nucl. Sci. **11**, 259 (1961).
[7] A Sperduto, M. I. T. Lincoln Laboratory Nuclear Science Progress Report, 1959, p. 105 (unpublished).
[8] G. A. Bartholomew and B. B. Kinsey, Can. J. Phys. **31**, 1025 (1953); L. V. Groshev, A. M. Demidov, V. N. Lutsenko, and L. I. Pelekhov, *Atlas of Thermal Neutron Capture Gamma Rays*, translated by J. B. Sykes (Pergamon Press, Inc., New York, 1959), p. 115.
[9] Samples obtained from Stable Isotope Sales, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
[10] D. Blatchley, L. M. Bollinger, and G. E. Thomas, (unpublished).

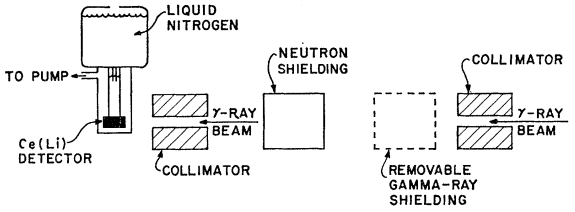

FIG. 1. Schematic representation of the Ge(Li) detector and collimator system.

possible, high-purity graphite sample holders were used. These containers afforded the double advantage of low capture cross section and of having only two lines in the spectrum. These lines, which have energies of 4946 and 3684 keV, served as convenient γ-ray energy standards. Nitrogen contamination was minimized by flowing He gas through the reactor tube. Other sources of background were materially reduced by appropriate shielding. A schematic representation of the beam collimator and Ge(Li) detector system is shown in Fig. 1. The Ge(Li) detector employed has a sensitive volume of 4 cm^3 and an energy resolution width of $\sim$6 keV at a deposited energy of 6 MeV.

The data were collected in a 4096-channel pulse-height analyzer. No electronic biasing arrangement was employed; the entire spectrum up to the highest energy was collected at the same time. To obviate the usual difficulties associated with electronic drifts, digital gain stabilization was always employed at the analyzer. No gain shift or line broadening was observed although runs lasted in excess of 24 h.

To facilitate accurate determinations of γ-ray energies, a series of pulser calibration lines (spaced at $\sim$60-channel intervals) was fed into the analyzer before and after each sample run. During the pulser calibration, the sample spectrum was allowed to enter the analyzer and the digital gain stabilizer was locked on the same Ag γ-ray peak as in the normal spectral runs. This ensured an accurate one-to-one correspondence between energy and channel number in calibration and sample runs. A sensitive and accurate determination of the various calibration pulse-heights was made by using a high-precision digital voltmeter to record the voltage stored on the pulser capacitor immediately ahead of the mercury switch.

The series of pulser peaks was used to sensitively trace the over-all linearity of the system. The linearity curve was traced in each region of interest by fitting the positions of a small number of pulser calibration peaks to a polynomial of second order. This proved to be sufficient since the coefficient of the second-order term was vanishingly small in virtually every region. It was observed that contact potentials or other effects produced a small but detectable digital voltmeter reading at zero pulse height. This zero correction required at least two accurately known energy standards to define the linear relation between pulse position and energy. For this purpose, the accurately determined energies of the carbon ground-state γ-ray (4945.4 keV)[11] and the Ar^{41} line (1293.4 keV),[12] present in all spectra, were employed.

The centroids of both the calibration peaks and the γ-ray peaks were accurately determined by computer; a variable-metric minimization program[13] fitted a Gaussian line shape to the peaks. In conjunction with the calibration method outlined above, this analysis was able to determine the γ-ray energies of the stronger and/or more isolated peaks with an uncertainty of $\sim$1 keV.

Figure 2 displays the relative double-escape-peak detection efficiency as a function of γ-ray energy for the detector-collimator system. This efficiency curve was determined empirically from a comparison of the peak heights observed with a nitrogen sample and the known[14] relative intensities of the transitions.

The analysis took account of the presence of double- and single-escape peaks, as well as of the full-energy peaks which were observed for the stronger transitions. Double-escape peaks were found to be about 10 times as intense as single-escape peaks, independent of energy. At E_γ=4 MeV, the efficiency for detection of double-escape peaks was observed to be $\sim$10 times that for full-energy peaks, and this ratio varied monotonically up to $\sim$20 at 6 MeV. However, some regions of these spectra were complicated by the close proximity of these various types of lines associated with different γ rays. To clarify these situations, the detector system was operated in a pair-spectrometer mode in which the Ge(Li) detector was straddled by two 4×4-in. NaI(Tl) detectors mounted 180° apart. The relatively poor geometry of this pair-spectrometer arrangement reduced the counting rate in the double-escape peaks to $\sim$5% of that obtained in the singles mode of operation. Hence, the pair mode was reserved mainly for clarification; singles spectra were used for the main analysis.

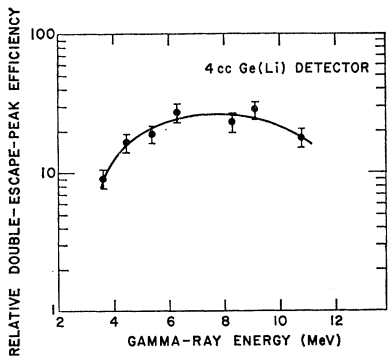

FIG. 2. Empirically determined relative double-escape-peak efficiency of the Ge(Li) and collimator system as a function of γ-ray energy.

[11] W. V. Prestwich (private communication).
[12] D. H. White (private communication).
[13] W. C. Davidon, Argonne National Laboratory Report No. ANL-5990 (Rev. 2), 1966 (unpublished).
[14] H. T. Motz, R. E. Carter, and W. D. Barfield, *Pile Neutron Research in Physics* (International Atomic Energy Agency, Vienna, 1962).

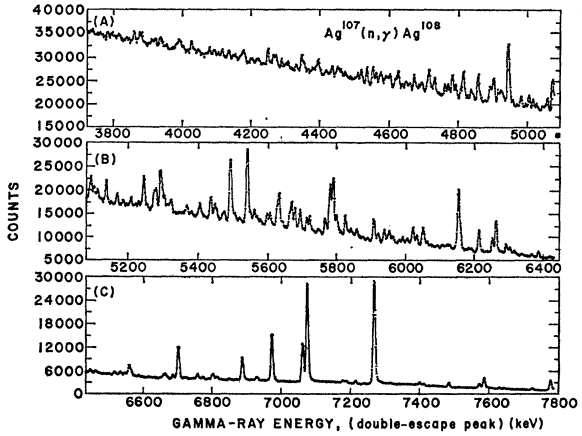

FIG. 3. Typical singles γ-ray spectrum observed for the reaction $Ag^{107}(n,\gamma)Ag^{108}$. The abscissa denotes the γ-ray energy to be associated with the double-escape peaks in the spectrum.

III. RESULTS

A. $Ag^{107}(n,\gamma)Ag^{108}$

Figure 3 displays a typical singles γ-ray spectrum obtained for the reaction $Ag^{107}(n,\gamma)Ag^{108}$. This spectrum was obtained in a run lasting 20 h. The γ-ray energies and relative intensities[15] of the primary transitions identified in Ag^{108} are listed in Table I. Because of the high enrichment of the sample (98.8% in Ag^{107}), all transitions listed have been unambigiously assigned to Ag^{108}. This spectrum showed no evidence for any of the lines observed in the subsequent study of the $Ag^{109}(n,\gamma)Ag^{110}$ reaction. The excitation energies of the terminal states have been obtained under the reasonable assumption that in this mass region γ rays that have energies within $\sim$2 MeV of the binding energy of the neutron are primary transitions. The neutron separation energy of Ag^{108} was determined to be (7265$\pm$1) keV. This agrees with the previous value of (7270$\pm$20) keV obtained by Bartholomew *et al.*[8] in their study of the same reaction, and also with the mass-adjusted value (7275$\pm$7) keV listed in the compilation of Mattauch *et al.*[16] Spectral complexities and other sources of uncertainty encountered for transitions with energies somewhat less than 6 MeV prevented a detailed analysis of γ rays much below this energy. However, 32 levels up to an excitation energy of $\sim$1300 keV were established in the present experiment and are listed in Table 1.

TABLE I. Summary of the γ-ray energies and intensities and the excitation energies of states populated in the thermal-neutron reaction $Ag^{107}(n,\gamma)Ag^{108}$.

Excitation energy (keV)	γ-ray energy (keV)	Relative intensity[a]	Excitation energy (keV)	γ-ray energy (keV)	Relative intensity[a]
0	7267±1	98 ±15	706	6561±1	10.0±1.5
79	7188±2	1.6± 0.9	879	6388±2	5.5±1.0
191	7076±1	100	897	6370±3	1.8±0.4
205	7062±1	38 ± 6	975	6292±3	2.6±0.5
285	6982±2	3.0± 0.6	1002	6265±1	27 ±4
293	6974±1	46 ± 7	1012	6255±1	13 ±2
333	6934±2	1.2± 0.2	1047	6220±1	21 ±4
338	6929±1	2.3± 0.4	1105	6162±1	19 ±3
451	6816±1	2.9± 0.5	1111	6156±1	57 ±9
460	6807±2	3.2± 1.0	1136	6131±2	3.3±0.7
465	6802±2	3.7± 0.9	1157	6110±2	3.0±0.6
508	6759±1	4.4± 0.7	1200	6067±2	2.2±0.4
547	6720±3	1.1± 0.4	1214	6053±1	15 ±3
563	6704±1	32 ± 5	1231	6036±2	9.3±1.6
578	6689±2	2.9± 0.6	1242	6025±2	18 ±3
606	6661±2	2.5± 0.6	1271	5996±2	5.8±1.0
699	6568±3	1.8± 0.8			

[a] The errors assigned to the relative intensities listed here also reflect an $\sim$15% uncertainty quoted for the intensities of the transitions in nitrogen (Ref. 14) which were used in the empirical determination of the relative double-escape-peak efficiencies of the Ge(Li) detector (Fig. 2). The strengths of all lines listed have been corrected for detector efficiency and have been normalized to that of the strongest transition (7076 keV) observed in the spectrum.

[15] No attempt was made to establish the intensities of these transitions in terms of percent per neutron capture, as is usually done, by comparing the relative intensities observed with those of Groshev *et al.* (Ref. 8). The spectra obtained by these authors contain too large a number of unresolved transitions for such a comparison to be feasible.

B. $Ag^{109}(n,\gamma)Ag^{110}$

A typical singles γ-ray spectrum observed in the $Ag^{109}(n,\gamma)Ag^{110}$ reaction is shown in Fig. 4. The experimental time required to obtain this spectrum was 21 h. Several regions in this spectrum, especially that between $\sim$6600 and $\sim$6900 keV, suffer from severe complication due to the juxtaposition of double-escape, single-escape, and full-energy peaks arising from various transitions present in the spectrum. The spectrum shown in Fig. 5 was obtained in 20 h of operation in the pair-spectrometer mode. This spectrum is distinctly simpler than the singles spectrum (Fig. 4).

The energies and relative intensities of the transitions assigned to this reaction are summarized in Table II. As a result of the high sample enrichment (99.1% in Ag^{109}) and the known γ-ray spectrum of the $Ag^{107}(n,\gamma)Ag^{108}$ reaction, all transitions listed in Table II were unambiguously categorized as occurring in Ag^{110}. As in the case of Ag^{108}, the excitation energies were established under the assumption that any γ-ray energy within $\sim$2 MeV of the neutron binding energy is a primary transition. The neutron-separation energy of Ag^{110}, established from the energy of the transition from the capture state to the ground state, is (6810$\pm$1) keV. This value is to be compared with the mass-adjusted value of (6824$\pm$7) keV given by Mattauch *et al.*[16] and the value of (6810$\pm$5) keV obtained from the (d,p) Q value of Mazari.[17] The density of lines below a γ-ray energy of $\sim$5500 keV prevented reliable analysis of the spectrum below this energy. Table II summarizes the 45 levels with excitation energies up to $\sim$1300 keV, which were established in the present experiment.

[16] J. H. E. Mattauch, W. Thiele, and A. H. Wapstra, Nucl. Phys. **67**, 32 (1965).

[17] M. Mazari, M. I. T. Lincoln Laboratory Nuclear Science Progress Report, 1957, p. 44 (unpublished).

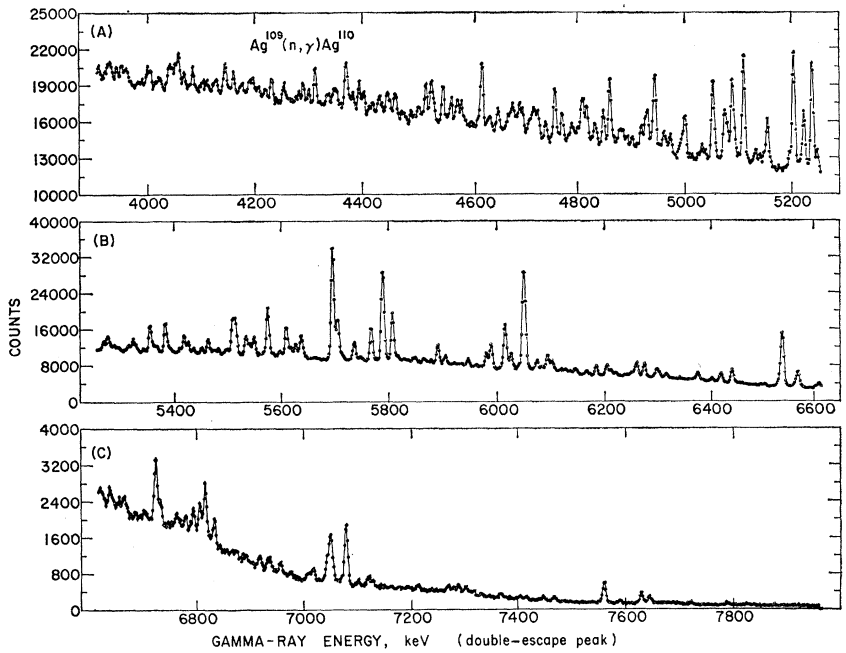

FIG. 4. Typical singles γ-ray spectrum observed for the reaction $Ag^{109}(n,\gamma)Ag^{110}$. The abscissa denotes the γ-ray energy to be associated with the double-escape peaks in the spectrum.

TABLE II. Summary of the γ-ray energies and intensities and the excitation energies of states populated in the thermal-neutron reaction $Ag^{109}(n,\gamma)Ag^{110}$.

Excitation energy (keV)	γ-ray energy (keV)	Relative intensity[a]	Excitation energy (keV)	γ-ray energy (keV)	Relative intensity[a]
0	6810±1	2.6± 0.4	775	6035±1	11 ± 2
197	6613±1	3.3± 0.6	786	6024±1	36 ± 6
238	6572±1	6.3± 0.9	813	5997±1	20 ± 4
248	6562±2	1.1± 0.5	825	5985±1	12 ± 2
270	6540±1	42 ± 7	857	5953±1	4.7± 0.8
360	6450±1	9.8± 1.4	897	5913±2	4.2± 1.3
381	6429±1	6.3± 1.1	906	5904±1	11 ± 2
416	6394±2	0.9± 0.3	992	5818±2	4.6± 1.0
426	6384±1	5.7± 0.9	1000	5810±1	41 ± 6
432	6378±2	0.8± 0.4	1017	5793±1	79 ±12
498	6312±2	3.4± 0.7	1037	5773±1	28 ± 4
525	6285±1	7.9± 1.3	1065	5745±1	17 ± 3
539	6271±1	12 ± 2	1089	5721±2	2.1± 0.4
548	6262±1	3.7± 0.7	1098	5712±1	31 ± 5
587	6223±1	4.0± 0.6	1107	5703±1	100
615	6195±1	6.5± 1.0	1166	5644±1	23 ± 4
633	6177±1	2.8± 0.6	1176	5634±1	13 ± 2
654	6156±3	0.7± 0.3	1185	5625±2	4.1± 0.8
698	6112±1	7.7± 1.4	1194	5616±1	27 ± 4
706	6104±1	12 ± 1	1229	5581±1	42 ± 7
727	6083±1	7.4± 1.2	1255	5555±1	17 ± 3
751	6059±1	87 ±13	1263	5547±1	10 ± 2
760	6050±2	2.0± 0.4	1270	5540±1	17 ± 3

[a] The listed errors were assigned as described in Ref. a of Table I, except that the strengths of the lines were normalized to the 5703-keV transition—the strongest one in this spectrum.

IV. CONCLUSIONS

Figures 6 and 7 show the Ag^{108} and Ag^{110} level schemes established in the present work. They extend somewhat above the highest state observed in (d,p) studies.[7,17] These figures also include levels previously reported in (d,p)[7,17] and (n,γ)[8] investigations and in studies[18] of decay of the long-lived isomeric spin-6 states.

Since primary dipole transitions are by far the most probable, all states observed to be directly populated from the 0^- or 1^- capture state of either nuclide can be assigned spins of 0, 1, or 2. On this basis, the primary population of these similar low-spin states in Ag^{108} and Ag^{110} may be compared. From the results listed in Tables I and II, there do not appear to be any systematic regularities or similarities in the decay of the

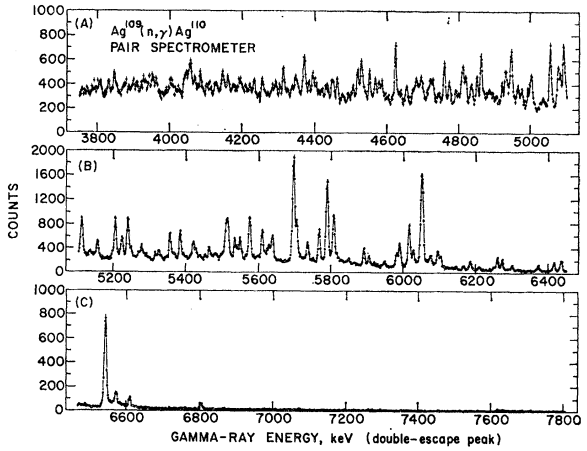

FIG. 5. Pair-spectrometer γ-ray spectrum observed for the reaction $Ag^{109}(n,\gamma)Ag^{110}$. Only double-escape peaks are present in this spectrum.

[18] *Nuclear Data Sheets*, compiled by K. Way *et al.* (Printing and Publishing Office, National Academy of Sciences—National Research Council, Washington 25, D. C.), NRC 58-3-52, 60-2-66.

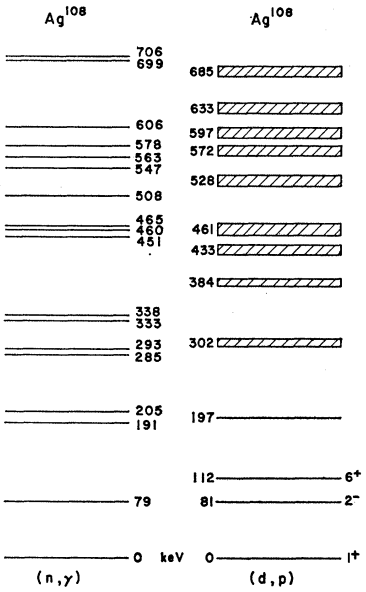

FIG. 6. Level scheme of Ag^{108} as determined from the present investigation (left) and previously reported (d,p), (n,γ), and isomeric-decay studies (right). The diagonally shaded areas denote the uncertainties in the positions of the states observed in the (d,p) reaction.

capture states of these nuclides. This is in contrast to similar studies[1–4] of the odd-A Hf and W nuclides, in which strong primary transitions were observed to selectively populate particular Nilsson orbitals for the five isotopes investigated. Indeed, in Ag^{108} the transition to the 1^+ ground state is one of the strongest seen, while in Ag^{110} the primary population to the 1^+ ground state appears as one of the weaker transitions observed. Lines of considerable strength populate levels close to the ground state in Ag^{108}. This is in contrast to the lack of any strong Ag^{110} transitions to levels below an excitation energy of ~ 700 keV. This lack of similarity is consistent with the wide fluctuations in the strengths of particular primary transitions predicted by Porter and Thomas[19] on the basis of the statistically complex and independent nature of the capturing states which gives rise to virtually randomly-constituted matrix elements connecting these states and low-lying excited states.

Particular notice should be taken of the 7188-keV transition to the 2^- first excited state at 79 keV in Ag^{108}. The established[20] negative parity of this state leads to an $M1$ assignment for this transition from the negative-parity capture state. The strength of this transition, only $\sim 2\%$ of that of the $E1$ transition to the 1^+ ground state, is consistent with the expected[6] dominance of transitions of the $E1$ type. The $M1$ transition to the elusive 2^- state expected at an excitation energy of ~ 30 keV in Ag^{110} is unfortunately masked in the singles spectrum by the relatively strong single-escape peak of the 6271-keV transition. Close examination of this peak indicates a very slight excess of counts over what is expected for this single-escape peak; this allows an upper limit of $<8\%$ to be assigned for the intensity of the possible 6782-keV transition to this 2^- state relative to that of the 6810-keV ground-state transition. Unfortunately, a transition of this intensity was too weak to be observed in the pair-spectrometer spectrum (Fig. 5).

As previously stated, the (d,p) reaction is expected to populate only the low-lying negative-parity states. Unfortunately, the accuracy of the existing (d,p) data[7,17] is inadequate for establishing a one-to-one correspondence between the levels populated in this reaction and those seen in the present experiment. In addition, these (d,p) studies did not include proton angular distributions which might have firmly established the parity of these states. However, some gross comparisons can be made. If only the expected negative-parity states are seen in the (d,p) studies, primary transitions terminating at these levels would be $M1$ radiation and would be expected to be much weaker than known $E1$ transitions. In this context, it is interesting to note that only in the vicinity of the 302- and 572-keV states in Ag^{108} reported in (d,p) work[7] are primary transitions of any appreciable strength seen to nearby states in the present study. All other (d,p) excited levels in both Ag^{108} and Ag^{110} are seen only in the proximity of states to which primary γ-ray population is relatively weak. This seeming anticorrelation may be evidence that these (d,p) levels are of negative parity and that consequently the primary transitions to these states are of $M1$ character. The unfortunate unavailability of a one-to-one identification between the states seen in the two reactions does not permit a more explicit statement of this anticorrelation. Improved (d,p) studies with higher resolution would be of considerable interest in checking these negative-parity assignments. Of course, complete angular-distribution

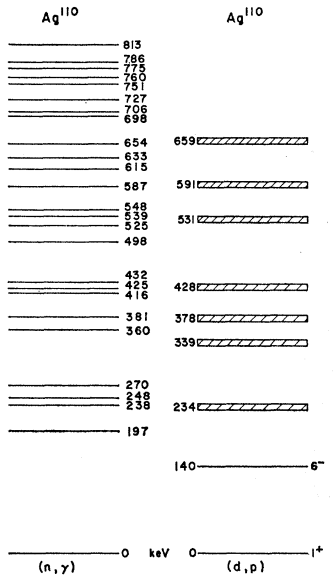

FIG. 7. Level scheme of Ag^{110} as determined from the present investigation (left) and previously reported (d,p), (n,γ), and isomeric-decay studies (right). The diagonally shaded areas denote the uncertainties in the positions of the states observed in the (d,p) reaction.

[19] C. E. Porter and R. G. Thomas, Phys. Rev. **104**, 483 (1956).
[20] *Nuclear Data Sheets*, compiled by K. Way *et al.* (Printing and Publishing Office, National Academy of Sciences—National Research Council, Washington 25, D. C.), NRC 58-3-47.

measurements of the outgoing proton groups would conclusively establish the parities of these levels. And this, when coupled with the present experimental (n,γ) results, would allow the desired comparison between $E1$ and $M1$ transition probabilities.

Finally, although some of the low-energy transitions in Ag^{110} observed by Kalinkin *et al.*[21] may be fitted between some levels seen in the present work, definitive assignments of the low-energy transitions and their placement in the decay scheme must await studies with higher resolution.

[21] L. F. Kalinkin, I. V. Estulin, and A. S. Melioranskii, Izv. Akad. Nauk. SSSR, Ser. Fiz. **28**, 227 (1964) [English transl.: Bull. Acad. Sci. USSR, Phys. Ser. **28**, 144 (1965).]

ACKNOWLEDGMENTS

The authors are indebted to Dr. J. Vervier for stimulating and helpful discussions. They also appreciate the valuable aid of G. E. Thomas, who designed the through-hole facility and installed the targets, and the assistance of C. E. Batson, who recorded and processed much of the data.

PHYSICAL REVIEW VOLUME 157, NUMBER 4 20 MAY 1967

Internal Conversion Coefficients with Relativistic Hartree-Fock Model for the Deformed Region

C. P. BHALLA*

Argonne National Laboratory†, Argonne, Illinois
University of Alabama Research Institute,‡ Huntsville, Alabama
and
Kansas State University, Manhattan, Kansas

(Received 17 August 1966; revised manuscript received 16 January 1967)

Internal conversion coefficients for $E2$ transitions in six cases of the deformed nuclear region are presented. New calculations are based upon the relativistic Hartree-Fock potential in the Slater-exchange approximation with the inclusion of only the static finite-nuclear-size effects. For the $2^+\rightarrow 0^+$ transitions in Gd^{156}, Dy^{160}, Er^{166}, Yb^{170}, Os^{186}, and Os^{188}, a comparison of present calculations with the weighted mean of all experimental values for L_1/L_2 indicates that the latter are larger by $(6.2\pm3)\%$, $(5.9\pm4.3)\%$, $(8.4\pm4.4)\%$, $(7.3\pm3.9)\%$, $(7.5\pm6.4)\%$, and $(2.8\pm5.6)\%$, respectively. Corresponding results for L_1/L_3 are $(5.5\pm1.8)\%$, $(5.5\pm2.5)\%$, $(6.3\pm2.3)\%$, $(5.5\pm2.4)\%$, $(6.6\pm4.6)\%$, and $(4.3\pm4.1)\%$. The uncertainties assigned to the percentage deviations correspond to an estimate of error at approximately 90% confidence level. Deviations of about the same magnitudes were pointed out by several experimentalists in a comparison with the calculations of Sliv and Band and of Rose. Numerical results are also given for the K subshell and M subshells in the above cases. It is suggested that M-subshell ratios be measured. A comparison of the experimental M-subshell ratios and K-conversion coefficient (within an accuracy of 2% or so) would provide additional information so that the origin of deviations in L-subshell ratios could be pinpointed. A possible explanation may be the effects of nuclear deformation on the L_1 internal conversion coefficient.

I. INTRODUCTION

THERE are two extensive calculations of internal conversion coefficients (ICC)—one by Rose and his collaborators[1] and the other by Sliv and Band.[2] These calculations have been used profitably for the last ten years or so; in fact, the contribution of these authors has been, and is, of utmost importance in the assignments of spins and parities in low-lying nuclear states. The common features of these two calculations are the inclusion of finite-nuclear-size effects (static effects) and the atomic screening considered by the statistical model of Thomas, Fermi, and Dirac (TFD). The main difference between the two models is that nuclear currents are taken to be of the form of delta functions at the nuclear surfaces in the model of Sliv and Band, in contrast to that of Rose, wherein no current is considered. It is to be noted that the contribution of the region inside a nucleus to the imaginary part of the conversion matrix element (and therefore to ICC) is different in the two calculations. In most cases of practical interest, such a contribution calculated by either procedures is expected to be much smaller than that from the region outside the nuclear radius. Consequently, one would expect that differences of a few percent in the results of Refs. 1 and 2 should occur. This in fact is true for most of the tabulated

* Permanent address: Kansas State University, Physics Department, Manhattan, Kansas.

† Part of this work was performed under the auspices of the U. S. Atomic Energy Commission.

‡ Supported, in part, by the National Aeronautics and Space Administration under Grant No. NsG-381.

[1] M. E. Rose, *Internal Conversion Coefficients* (North-Holland Publishing Company, Amsterdam, 1958).

[2] L. A. Sliv and I. M. Band, *Coefficients of Internal Conversion of Gamma-Radiation* (USSR Academy of Sciences, Moscow-Leningrad, 1956), Part I and Part II. Also see L. A. Sliv and I. M. Band, in *Alpha-, Beta-, and Gamma-Ray Spectroscopy*, edited by K. Siegbahn (North-Holland Publishing Company, Amsterdam, 1965), Vol. 2.