Neutron resonance spectroscopy of ^{107}Ag and ^{109}Ag

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Parity violation has been observed in a number of previously unreported neutron resonances in silver. Analysis of these parity violation data requires improved neutron resonance spectroscopy. The neutron total cross section for natural silver was measured for $E_n = 10-800$ eV with the time-of-flight method at the Los Alamos Neutron Scattering Center. The neutron capture reaction was studied with both a natural silver target and a highly enriched sample (98.29%) of ^{107}Ag. A total of 38 previously unreported resonances were observed. The combination of the two measurements allowed assignment of the newly observed resonances to ^{107}Ag or to ^{109}Ag. Resonance parameters were determined for almost all of the neutron resonances observed. [S0556-2813(97)00807-8]

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I. INTRODUCTION

The traditional view of symmetry breaking in the nucleus is exemplified by the approach to parity nonconservation (PNC) in light nuclei. Parity doublets (closely spaced, low-lying states of the same angular momentum and opposite parity) were studied. A parity-forbidden observable was measured and the wave functions for the initial and final states were calculated with the shell model. After the discovery [1] of a very large enhancement of parity violation for neutron resonances in heavy nuclei (as large as 10^6!), a new approach was adopted that considers the compound nucleus as a chaotic system and treats the symmetry breaking matrix elements as random variables. The experimental goal of the parity violation experiments is the determination of the root-mean-square symmetry breaking matrix element. The compound nucleus is now considered as an excellent laboratory for the study of symmetry breaking. The change in approach is illustrated by the difference between the classic review by Adelberger and Haxton [2] and the recent reviews by Bowman *et al.* [3] and by Flambaum and Gribakin [4].

In all of the early experiments only one parity violation was measured per nuclide, due to the very limited sensitivity and energy range studied. This is a crucial limitation, since a number of measurements are required for the statistical analysis. The TRIPLE Collaboration has measured a number of parity violations in ^{238}U [5,6] and ^{232}Th [7,8] (providing data suitable for the determination of a rms PNC matrix element). The initial measurements were performed for targets that are near the maximum of the $4p$ neutron strength function. To determine whether the effective nucleon-nucleus weak interaction has a mass dependence it is important to obtain data near the $3p$ neutron strength function maximum at $A \approx 110$. It is also important to determine whether the unexpected nonstatistical result observed in ^{232}Th [7,8] (where all asymmetries measured have the same sign) is general or specific to ^{232}Th. Recent measurements [9] have confirmed the existence of the sign correlation in ^{232}Th with a high degree of confidence.

As the atomic number is reduced from $A \approx 230$ to $A \approx 110$, the level density decreases. The size of the observed parity violation is proportional to the level density. In order to obtain level densities in this mass region that are comparable to those in the earlier experiments, one must use odd-mass targets. Due to its mass value (very close to the $3p$ neutron strength function maximum), availability, and level density, silver seemed a prime candidate as a target for parity violation studies. We measured the helicity dependence of the neutron total cross section of natural silver [10]. Silver consists of two isotopes with nearly equal abundances (51.8% ^{107}Ag and 48.2% ^{109}Ag). Since the neutron resonance spectroscopy for silver had not been studied since 1969 [11], with our improved experimental sensitivity we expected to observe additional resonances. Our expectations were fulfilled as we observed nearly 40 previously unreported resonances. Following the experiment with natural silver we studied a target enriched in ^{107}Ag in order to identify the isotope to which the new resonances belonged. This information proved invaluable, since in the parity violation experiment with natural silver, eight of the ten statistically significant parity violations observed [10] were for resonances that were previously unreported.

We describe our experimental methods in Sec. II and dis-

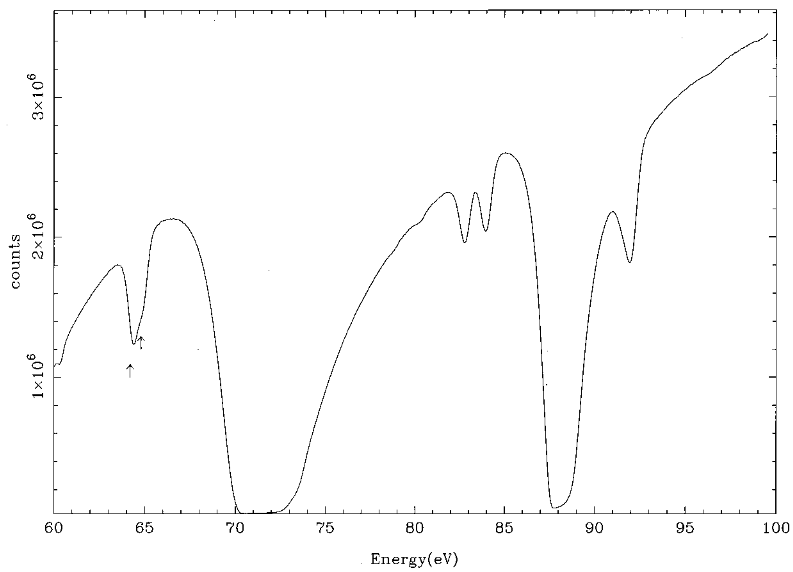

FIG. 1. Neutron transmission spectrum for natural silver in the energy range E_n = 60–100 eV. The arrows indicate two resonances that had not been previously observed.

cuss the identification of the newly observed resonances (assignment to ^{107}Ag or ^{109}Ag) in Sec. III. We describe the analysis methods and present the results for the resonance parameters in Sec. IV. The last section gives a brief summary.

II. EXPERIMENTAL METHOD

800-MeV protons from the Los Alamos Neutron Scattering Center (LANSCE) linac are injected into a proton storage ring (PSR) and compressed to pulses of short length. The extracted proton pulse strikes a tungsten target and neutrons are produced by the spallation process. The neutrons are then moderated to epithermal energies in a water moderator. A detailed description of the target-moderator geometry at LANSCE is given by Lisowski *et al.* [12]. An overview of the TRIPLE Collaboration experimental setup is given by Roberson *et al.* [13]. The TRIPLE beam line, associated neutron and γ-ray detectors, and data acquisition system were used in the measurements on silver reported in this paper.

The neutrons were detected by a system of 55 ^{10}B liquid scintillators [14] located at 56 m from the neutron source. The natural silver (2986 g, 99.999% chemical purity) target was formed by combining two cylinders, each 10.5 cm in diameter and of length 4.3 cm. The silver sample was located at the exit of the neutron spin rotation device, approximately 9.7 from the neutron source. The target was cooled to liquid nitrogen temperature (77 K) to reduce Doppler broadening of the resonance. Target-in and target-out transmission spectra were measured under identical conditions. The transmission spectra were corrected for electronic and detector dead times and for the gamma-ray background in the neutron beam [15]. For the parity violation measurements (requiring detailed analysis of the resonance shape and background for the weak p-wave resonances) our focus was on the energy region below 500 eV. However, with this experimental arrangement information about the resonances could be obtained in the

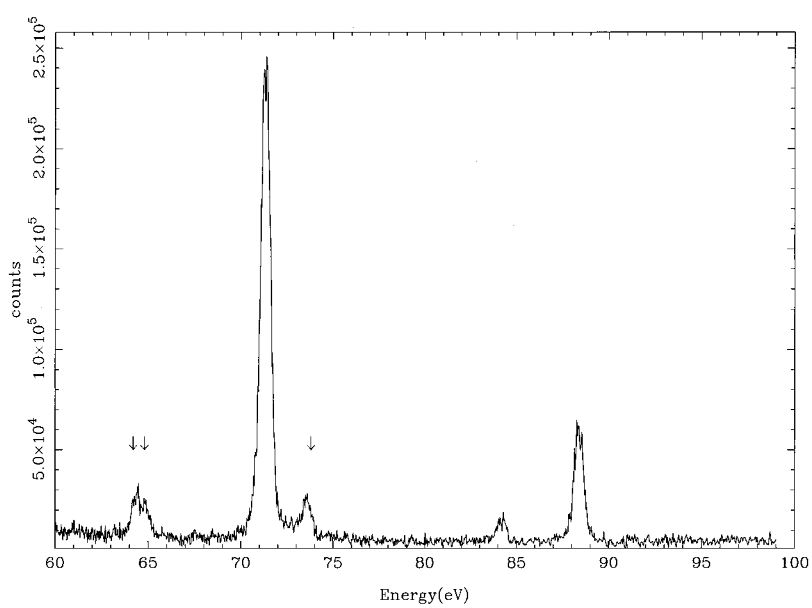

FIG. 2. The γ-ray yield for ^{107}Ag in the energy range E_n = 60–100 eV. The arrows indicate that the two new resonances observed in the transmission spectrum belong to ^{107}Ag. An additional new resonance in ^{107}Ag is also observed. This resonance (near 73 eV) was obscured in the transmission spectrum by a large s-wave resonance.

energy range 10−800 eV. A sample time-of-flight transmission spectrum in the energy region 60−100 eV is shown in Fig. 1. The arrows indicate the locations of two resonances that had not been observed previously. These new resonances do not correspond to any known contaminant resonances.

An additional measurement was performed on a highly enriched (98.29% ^{107}Ag) sample obtained from the Oak Ridge National Laboratory Isotopes Distribution Office. The enriched sample was 49.813 g of silver powder. The powder was uniformly distributed within an aluminum cylinder of diameter 8.9 cm with walls 0.05 cm thick. Since there was insufficient material to perform a transmission measurement, the neutron capture reaction was studied instead. For p-wave resonances at low energies the total width is essentially equal to the capture width. In order to facilitate comparison, capture γ-ray measurements also were performed with a natural silver sample (23.92 g) of the same chemical purity as used for the transmission measurements.

The γ-ray measurements were made with the silver target placed at a distance of 60 m from the neutron source. The γ-ray detector consisted of dual annular detectors with each annulus containing 12 trapezoidal scintillators of CsI(pure) joined in a ring of 20 cm inside diameter and 40 cm outside diameter. The length of each annulus is 15 cm, giving a total detector thickness of 30 cm. The signals from the 24 detector elements are linearly summed in pairs such that the two annular rings are equivalent to one ring of 12 elements. The detailed characteristics and the shielding arrangements are described by Frankle *et al.* [16].

Analog detector outputs were recorded by a transient digitizer; the digitized signals were stored in 8192 time-of-flight channels. A sample time-of-flight spectrum for neutron energies between 60 and 100 eV is shown in Fig. 2. The two new resonances observed in the transmission spectrum are also present in this capture spectrum, establishing that the resonances are in ^{107}Ag. In addition, another previously unidentified resonance was observed. This resonance was obscured in the transmission spectrum by a nearby s-wave resonance.

TABLE I. $g\Gamma_n$ for new resonances in ^{107}Ag and ^{109}Ag.

E_n	$g\Gamma_n$ (meV)
18.9	0.000011
20.3	0.00012
32.7 [a]	0.007
35.84	0.00029
42.81	0.0035
64.24	0.019
64.74	0.013
73.21	0.027
78.5 [a]	Cannot determine $g\Gamma_n$
79.8 [a]	Cannot determine $g\Gamma_n$
101.2	0.004
107.6	0.010
110.8	0.089
125.1	0.006
126.1	0.016
136.7	0.018
141.5	0.010
160.3 [a]	0.015
164.3 [a]	0.014
183.5	0.168
199.0 [a]	0.028
201.0	0.186
219.2 [a]	0.063
228.3	0.046
231.0	0.036
235.5	0.025
275.8 [a]	0.053
284.0 [a]	0.106
351.4 [a]	0.055
384.9	0.027
422.5	0.116
430.0 [a]	Cannot determine $g\Gamma_n$
503.8	0.269
521.7	0.685
592.4	0.65
600.8	0.457
661.3	0.151
778.8	9.14

[a]Resonances assigned to ^{109}Ag.

III. RESONANCE IDENTIFICATION

The transmission data yield 38 resonances that had not been observed in previous measurements. The compilation of Mughabghab *et al.* [17], for both ^{107}Ag and ^{109}Ag, lists more s-wave resonances observed than p-wave resonances. In the simplest statistical model, for spin 1/2 particles on an $I=1/2$ target, the number of p-wave resonances should be about 2.25 times the number of s-wave resonances. Clearly most of the p-wave resonances were not observed in the earlier measurements.

By comparing capture spectra for natural-silver and enriched-silver targets, the new resonances were assigned either to ^{107}Ag or ^{109}Ag. Several resonances not visible in the transmission spectra were also observed and assigned. (In the thick natural silver target a number of resonances are obscured by large s-wave resonances or by resonances in the other isotope.)

The new resonances are listed in Table I. Resonances listed without an asterisk were observed in the enriched sample of ^{107}Ag. Resonances observed in the enriched sample clearly belong to ^{107}Ag. The absence of a resonance that was observed with the natural sample in transmission strongly suggests but does not ensure that the resonance belongs to ^{109}Ag, since the threshold of observability in the two experiments could be different. The capture experiment could fail to observe all of the new levels below a certain strength in either isotope. However, in the capture experiment we observe resonances that were the weakest of the newly observed resonances in the transmission experiment. Therefore it is reasonable to assign to ^{109}Ag the new resonances observed in transmission but not in capture. The direct comparison of the capture spectra for the enriched and natural targets provides definitive assignments. Of these new resonances 27 were assigned to ^{107}Ag and 11 to ^{109}Ag.

The new resonances assigned to ^{107}Ag were combined with the previously observed ^{107}Ag resonances and are listed in Table II. Table III does the same for ^{109}Ag. In both of these tables the new resonances are indicated by a dagger. In addition to assigning the new resonances to the appropriate isotope, a few resonances that had been observed previously were reassigned from one isotope of silver to the other. In most cases these resonances had been assigned to ^{109}Ag, but were observed with the enriched ^{107}Ag target.

IV. RESONANCE ANALYSIS

A. Determination of $g\Gamma_n$

The target-in and target-out data were corrected for dead time, and the γ-ray background removed [15]. Then a transmission spectrum was created by dividing the monitor-normalized target-in data by the monitor-normalized target-out data. The neutron widths were obtained from an area analysis of the resonances [18,19]. This method is particularly suitable for weak p-wave resonances. For a weak resonance ($n\sigma_0 < 0.5$),

$$A_n = \frac{\pi}{2} n\sigma_0 \Gamma \propto g\Gamma_n, \tag{1}$$

where σ_0 is the peak total cross section of the resonance. The neutron widths of 36 resonances were determined in the energy range 30−500 eV. In the thick natural silver target many of the resonances were obscured by large s-wave resonances or by resonances in the other isotope.

As noted above, comparison of the ^{107}Ag capture spectrum with the natural silver capture spectrum led to the isotopic assignment of the new resonances. In addition several resonances that were not visible in the transmission spectra were observed in the capture spectra. The neutron widths were obtained from an area analysis of the capture peaks with the relation

$$\sum N_\sigma = \Phi(E)\epsilon(E)A_n \frac{\Gamma_\gamma}{\Gamma}, \tag{2}$$

where $\Phi(E)$ is the neutron flux per eV, $\epsilon(E)$ is the detector efficiency, and A_n is given by Eq. (1). The quantity ΣN_σ is the measured yield of the resonance. The product $\Phi(E)\times\epsilon(E)$ was determined from the areas of resonances with well-known widths. From this information the energy dependence of the flux was determined to be $E^{-0.96}$, which agrees with the value of $E^{-0.9}$ quoted by Roberson *et al.* [13]. The neutron widths were determined with the area analysis method for 47 resonances in the energy range 10–800 eV for ^{107}Ag and 10–500 eV for ^{109}Ag.

These results were combined with the widths determined in the transmission measurements. The resonance parameters for ^{107}Ag are listed in Table II and the resonance parameters for ^{109}Ag are listed in Table III. For a few resonances that were either not visible in the transmission data or isolated in the capture data, it was not possible to determine the width.

B. Determination of orbital angular momentum

The Bayesian method adopted by Bollinger and Thomas [20] was used to determine the orbital angular momentum values of the resonances as $\ell = 0$ or 1. The Bayesian analysis used the measured widths together with strength functions and level densities from Mughabghab *et al.* [17]. The key to the analysis is that the difference in penetrabilities for the s- and p wave resonances is so large that most of the weaker resonances are p wave and most of the stronger resonances are s wave.

Following Frankle *et al.* [21], the Bayes probability for a specific resonance to be p wave for an $I=1/2$ target is

$$P = \frac{1}{1+(4/9)\sqrt{(4/3)[c^0(E)/c^1(E)](S^1/S^0)}\exp\{-(g\Gamma_n/2)[c^0(E)/D_0][(1/S^0)-(3/4S^1)[c^1(E)/c^0(E)]]\}}, \tag{3}$$

where S^0 and S^1 are the s- and p-wave strength functions, respectively, D_0 is the s-wave average level spacing, and the c^ℓ parameters relate the laboratory and reduced widths

$$g\Gamma_n^\ell = c^\ell(E) g\Gamma_n, \tag{4}$$

with the c^ℓ parameters given by

$$c^0(E) = \frac{1}{\sqrt{E(\text{eV})}} \quad \text{and} \quad c^1(E) = \frac{5.9\times10^5}{E^{\frac{3}{2}}(\text{eV})}. \tag{5}$$

With equal *a priori* s- and p-wave probabilities and a Porter-Thomas distribution, the Bayesian probability is $P=0.69$. Resonances with a probability greater than 0.69 were assigned as p wave and less than 0.69 were assigned as s wave. Obviously the assignment is less reliable for resonances with P close to 0.69. The probabilities and angular momentum assignments are listed in Tables II and III. As expected, almost all of the newly observed resonances are rather weak and are assigned as p wave resonances.

C. Determination of the s-wave spins

Neutron capture measurements have been performed at IRMM in Belgium by Zanini *et al.* [22] with a highly enriched ^{109}Ag target. These measurements have determined the spins of many of the resonances in ^{109}Ag. Although a precise one-for-one agreement is not expected between our measurements and those by Zanini *et al.* (the two capture measurements studied targets enriched in different isotopes and with different experimental sensitivity), the overall agreement is excellent. Their spin assignments for the new resonances (and for known resonances when the new assignments disagree with the earlier compilation [17]) are listed in Table III. Similar preliminary results for ^{107}Ag are included in Table II.

TABLE II. Neutron resonance parameters for ^{107}Ag.

E_n (eV)	$g\Gamma_n$ (meV)	Bayesian probability	ℓ	J	Comments
−11.1				1	
16.3±0.02	2.9±0.2	0.00	0	0	
18.9±0.02 [a]	$(1.1\pm1.5)10^{-4}$	0.99	1		
20.3±0.02 [a]	$(1.2\pm0.6)10^{-4}$	0.99	1		
35.84±0.03 [a]	$(2.9\pm1.5)10^{-4}$	0.99	1		
41.57±0.05	4.5±0.3	0.00	0	1	
42.81±0.03 [a]	$(3.5\pm2.1)10^{-3}$	0.99	1		
44.90±0.03	0.89±0.2	0.00	0	0[c]	
51.56±0.05	23.4±1.9	0.00	0	1	
64.24±0.05 [a]	0.019±0.003	0.98	1		
64.74±0.05 [a]	0.013±0.002	0.98	1		
73.21±0.06 [a]	0.027±0.004	0.98	1		
83.55±0.07	0.017±0.004	0.98	1		Previously assigned to ^{109}Ag
101.2±0.1 [a]	0.004±0.003	0.98	1		
107.6±0.1 [a]	0.010±0.005	0.98	1		
110.8±0.1 [a]	0.089±0.006	0.96	1		
125.1±0.1 [a]	0.006±0.004	0.97	1		
126.1±0.1 [a]	0.016±0.005	0.97	1		
128.5±0.1	0.092±0.006	0.96	1		
136.7±0.1 [a]	0.018±0.003	0.98	1		
141.5±0.1 [a]	0.010±0.002	0.98	1		
144.2±0.1	6.36±0.5	0.00	0	0	
154.8±0.1	0.033±0.005	0.97	1		
162.0±0.2	0.32±0.08	0.89	0[c]		
166.9±0.2	0.15±0.05	0.95	1		
173.7±0.2	10.3±1.0	0.00	0	1	
183.5±0.2 [a]	0.168±0.1	0.95	1		
201.0±0.2 [a]	0.186±0.1	0.95	1		
202.6±0.2	14.6±0.1	0.00	0	1	
218.9±0.2	0.085±0.03	0.97	1		
228.3±0.2 [a]	0.046±0.03	0.97	1		
231.0±0.2 [a]	0.036±0.05	0.97	1		
235.5±0.2 [a]	0.025±0.05	0.97	1		
251.3±0.3	27.6±6	0.00	0		
259.9±0.3	0.209±0.08	0.95	1		
264.5±0.3	2.1±0.3	0.16	0		
269.9±0.4	0.258±0.1	0.95	1		
310.8±0.4	98±5	0.00	0	1	
328.2±0.4	0.387±0.02	0.94	1		
346.8±0.4	0.289±0.06	0.95	0[c]		
359.7±0.4	0.264±0.1	0.95	1		
361.2±0.4	15.5±1.1	0.00	0	1	
372.5±0.5	0.197±0.02	0.96	1		
381.8±0.5	0.291±0.05	0.96	0[c]		
384.9±0.5 [a]	0.027±0.05	0.96	1		
403.9±0.5	0.296±0.08	0.95	1		
409.2±0.5	0.359±0.16	0.94	1		
422.5±0.6 [a]	0.116±0.05	0.96	1		
444.0±0.6	22.6±3.2	0.00	0	0[b]	
460.9±0.6	11.5±2.5	0.00	0	1[c]	
466.8±0.6	60.5±13	0.00	0	1	
472.4±0.6	14.0±2	0.00	0	0[b]	
479.3±0.7	0.457±0.3	0.94	1		
494.9±0.7	0.48±0.12	0.94	1		Previously assigned to ^{109}Ag

TABLE II. (*Continued.*)

E_n (eV)	$g\Gamma_n$ (meV)	Bayesian probability	ℓ	J	Comments
503.8 ± 0.7 [a]	0.269 ± 0.09	0.95	1		
514.7 ± 0.7	50.0 ± 5.5	0.00	0		Previously assigned to ^{109}Ag
521.7 ± 0.7 [a]	0.685 ± 0.2	0.93	1		
524.4 ± 0.8	1.01 ± 0.4	0.91	0[c]		
531.2 ± 0.8	0.377 ± 0.2	0.95	1		
553.8 ± 0.8	163 ± 30	0.02	0	0	
575.8 ± 0.9	9.01 ± 4	0.00	0	1	
586.9 ± 0.9	96.2 ± 0.1	0.00	0	1[b]	$J=0$ Mughabghab
592.4 ± 0.9 [a]	0.65 ± 0.2	0.93	1		
600.8 ± 0.9 [a]	0.457 ± 0.13	0.94	1		
607.3 ± 0.9	2.82 ± 0.6	0.75	1		
624.9 ± 1.0	16.1 ± 3	0.00	0		
634.1 ± 1.0	0.212 ± 0.1	0.95	1		Previously assigned to ^{109}Ag
647.9 ± 1.0	1.13 ± 0.4	0.91	0[c]		Previously assigned to ^{109}Ag
652.5 ± 1.0	12.4 ± 2	0.00	0		
661.3 ± 1.1 [a]	0.151 ± 0.1	0.95	1		
673.7 ± 1.1	63.7 ± 0.1	0.00	0		
694.8 ± 1.1	14.9 ± 1.6	0.00	0		
702.1 ± 1.1	2.89 ± 0.3	0.80	1		
720.7 ± 1.2	1.85 ± 0.1	0.88	0[c]		
737.3 ± 1.2	0.456 ± 0.15	0.94	1		
751.8 ± 1.3	66.2 ± 0.1	0.00	0		
778.8 ± 1.3 [a]	9.14 ± 0.1	0.00	0		

[a]New resonances.
[b]Spins assigned by this work.
[c]Preliminary assignment from Ref. [23].

However, for ^{107}Ag the spins of many of the s-wave resonances were not known, and no p-wave resonance spins were known. Knowledge of the spins of the s-wave resonances is very important in the determination of the rms PNC matrix element [24]. The spins of several of the unknown ^{107}Ag s-wave resonances were determined from an area analysis of the capture data. From Eq. (2), the area of the peak in the capture γ-ray spectrum is proportional to the ratio Γ_γ/Γ. For weak resonances Γ_n is much less than Γ_γ and therefore this ratio is close to unity. However, for s-wave resonances in silver, Γ_n is comparable to Γ_γ. Therefore one can use this empirical ratio to determine the statistical weight factor g, and from the value of g determine the total spin J.

Since Γ_γ and the product $g\Gamma_n$ are known from previous measurements [17], the quantity A_n can be calculated using Eq. (1). With a value of A_n and the experimental value of the area in the capture resonance, the ratio Γ/Γ_γ can be obtained. Since $\Gamma=\Gamma_n+\Gamma_\gamma$, the statistical weight factor is

$$g=\frac{g\Gamma_n}{\Gamma_\gamma}\frac{1}{\Gamma/\Gamma_\gamma-1}. \qquad (6)$$

From the experimental value of the ratio Γ/Γ_γ and the previously determined values of Γ_γ and $g\Gamma_n$, the statistical weight factor g can be determined.

For spin $i=1/2$ neutrons on an $I=1/2$ nuclide such as ^{107}Ag or ^{109}Ag, the statistical weight factor $g=(2J+1)/[(2i+1)(2I+1)]=(2J+1)/4$. Since the spins of s-wave resonances are $J=0$ or 1, the allowed values of g are 1/4 or 3/4. Therefore, if Γ_n is about equal to Γ_γ, the s-wave resonance spin can be determined. This method was used to confirm the J values quoted by Mughabghab [17] and to determine the spin of four additional s-wave resonances in ^{107}Ag. These spins are listed in Table II.

D. Strength functions

Overall trends in the data can be examined conveniently with the cumulative sums of the widths $g\Gamma_n$ and the reduced widths $g\Gamma_n^\ell$. No anomalies are observed in these plots, consistent with the expected statistical behavior. However, there are too few resonances for a detailed statistical analysis.

The values of the strength functions

$$S^\ell=\langle g\Gamma_n\rangle/(2\ell+1)D_\ell \qquad (7)$$

were determined for $\ell=0$ and 1 for ^{107}Ag and for ^{109}Ag:
$10^4S^0(^{107}\mathrm{Ag})=0.53\pm0.13$,
$10^4S^1(^{107}\mathrm{Ag})=8.9\pm1.9$,
$10^4S^0(^{109}\mathrm{Ag})=1.0\pm0.28$,
$10^4S^1(^{109}\mathrm{Ag})=3.9\pm1.3$.

The fractional uncertainties in the strength functions are calculated as $\pm(2/N)^{1/2}$, where N is the number of resonances in each data set. These strength functions are in reasonable agreement with those quoted by Mughabghab [17].

V. SUMMARY

The neutron total cross section was measured for natural silver for $E_n=10-800$ eV. The neutron capture reaction was

TABLE III. Neutron resonance parameters for ^{109}Ag.

E_n (eV)	$g\Gamma_n$ (meV)	Bayesian probability	ℓ	J	Comments
5.19±0.01	9.5±0.3	0.00	0	1	
30.6±0.02	6.33±0.5	0.00	0	1	
32.7±0.03 [a]	0.007±0.003	0.98	1	1[b]	
40.3±0.04	3.24±0.4	0.00	0	1	
55.8±0.04	11.6±1.3	0.00	0	0	
71.0±0.04	22.5±1.2	0.00	0	1	
78.5±0.06 [a]			1		Cannot determine $g\Gamma_n$
79.8±0.06 [a]			1		Cannot determine $g\Gamma_n$
82.5±0.06	0.016±0.004	0.98	1	2[b]	Previously assigned to ^{107}Ag
87.7±0.1	4.87±0.3	0.00	0	1	
91.5±0.1	0.025±0.01	0.98	1	2[b]	
106.3±0.1	0.055±0.02	0.95	1	0[b]	
113.5±0.1	0.034±0.005	0.98	1		
133.9±0.1	73.4±10	0.00	0	1	
139.6±0.1	0.881±0.1	0.00	0	1[b]	
160.3±0.2 [a]	0.015±0.005	0.99	1	1[b]	
164.3±0.2 [a]	0.014±0.005	0.99	1	2[b]	
169.8±0.2	0.20±0.05	0.78	0[b]	0[b]	
173.1±0.2	43.3±3.0	0.00	0	1	
199.0±0.2 [a]	0.028±0.005	0.98	1	1[b]	
209.2±0.2	28.8±2.9	0.00	0	1	
219.2±0.2 [a]	0.063±0.016	0.98	1	2[b]	
251.2±0.2	9.2±1.2	0.00	0	1	
259.0±0.3	1.1±0.3	0.00	0	0[b]	
272.4±0.3	2.63±0.5	0.00	0	1[b]	
275.8±0.3 [a]	0.053±0.008	0.98	1		
284.0±0.3 [a]	0.106±0.010	0.97	1	2[b]	
290.6±0.3	8.21±1.3	0.00	0	1[b]	
293.3±0.3	0.17±0.1	0.95	1	1[b]	
300.9±0.4	0.7±0.3	0.38	0	0[b]	
316.2±0.4	149±20	0.00	0	1	
322.1±0.4	0.11±0.07	0.97	1		
327.8±0.4	0.43±0.3	0.83	0[b]	1[b]	
340.2±0.4	0.13±0.04	0.97	1	2[b]	
351.4±0.4 [a]	0.055±0.01	0.98	1	2[b]	
386.2±0.5	41.5±1.9	0.00	0	1	
391.6±0.5	0.16±0.05	0.97	1	1[b]	
397.3±0.5	19.2±1.1	0.00	0	1	
401.7±0.5	63.9±10.5	0.00	0	0	
427.9±0.6	13.7±2.0	0.00	0	1[b]	
430.0±0.6 [a]				1[b]	Cannot determine $g\Gamma_n$
441.0±0.6	0.10±0.04	0.99	1	1[b]	
469.7±0.6	34.5±2.1	0.00	0	0	
487.0±0.7	17.1±1.5	0.00	0	1[b]	
495.2±0.7	0.45±0.2	0.92	1		
499.8±0.7	115±10.8	0.00	0	1	

[a]New resonances.
[b]Preliminary assignment from Ref. [22].

studied in the same energy range for a natural silver target and a highly enriched ^{107}Ag target. A total of 38 previously unreported resonances were observed. Of these new resonances 27 were assigned to ^{107}Ag and 11 to ^{109}Ag. Previous isotopic assignments in the literature were changed for several weak resonances. The product $g\Gamma_n$ was determined by area analysis for 36 resonances in the transmission data and for 47 resonances in the capture data. Orbital angular momentum assignments were obtained with a Bayesian analysis.

The isotopic assignment of these new resonances is crucial for the parity violation studies in natural silver [10]. The additional spectroscopic information (strength, ℓ-value, spin) is also very important for the determination of the rms PNC matrix element [24].

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