sees that the results decrease monotonically with increasing A, so that if one assumes an A^{-n} dependence, n must be greater than 1/3; the data of Table I indicate that $n=0.53\pm0.09$. It is interesting to note here that Nilsson's calculations assume that the numbers in column (6) of Table I should all be 2.05; this is a reasonable average, but it is certainly a gross oversimplification of the actual situation.

There has been much interest lately in the variation of "effective mass," m^*, of nucleons with binding energy.[16] The variation of spin-orbit splittings (after correction for l-dependence) may perhaps be considered as such an effect. The fact that the splitting of the d states is somewhat smaller than that of the p and f states in Pb^{207} would then indicate that m^* for a neutron is somewhat larger at 1.7-MeV binding energy (d-states) than at 7.0-MeV (p-states) or 5.8-MeV (f-states) binding energy in Pb.[17]

An interesting application of Table I is to use the systematics implied therein to predict locations of unknown or doubtful levels. For example, in Ni^{59} one expects the $d_{5/2}$-$d_{3/2}$ splitting to be about 3.0 MeV. This is somewhat larger than assumed in reference 17, but somewhat smaller than assumed in reference 5.

ACKNOWLEDGMENT

The authors are greatly indebted to R. A. Sorenson for very helpful discussions.

[16] G. E. Brown (private communication).

[17] This point was elucidated in discussions with J. P. Schiffer.

[18] J. P. Schiffer, L. L. Lee, Jr., and B. Zeidman, Phys. Rev. **115**, 427 (1959).

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Resonance Capture γ Rays from Platinum*

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The high-energy gamma rays following neutron capture in a platinum target have been studied at the Brookhaven-AECL fast chopper facility at Chalk River. The transitions to the 0^+ ground state and the first two excited 2^+ states in Pt^{196} have been measured for 15 resonances from 11.9 to 296 eV. Relative transition probabilities for these cases have been determined and are compared to the chi-squared class of probability distribution functions.

INTRODUCTION

FOR the past several years considerable interest has been growing in the measurement of γ rays accompanying the de-excitation of the states formed by the capture of slow and intermediate energy neutrons.[1] The utilization of pulsed sources and time-of-flight techniques permits a study of the radiation from individual resonances and represents an advance over the thermal capture γ-ray work, where a mixture of capturing states is usually involved. The resonance measurements have been directed toward the determination of quantum numbers of the capturing state[2-5] (principally the angular momentum J), the isotopic identification of resonances,[2,4,6,7] and the study of the size and distribution in size of the widths for de-excitation to the various final states in the product nucleus.[3,4,6,8-13] The present paper is concerned with the latter topic.

Early work in this field showed that capture γ-ray spectra from the various resonances of the same spin state display marked differences.[9] However, initial experiments on the partial radiation widths to states near the ground state indicated little variation from resonance to resonance.[8] In this early work it was not always possible to separate adjacent γ-ray lines. Theoretical considerations indicate that transitions which feed

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[1] G. A. Bartholomew, Ann. Rev. Nuclear Sci. **11**, 259 (1961). This review gives a comprehensive picture of neutron capture γ-ray studies, both at thermal and in resonances.

[2] J. D. Fox, R. L. Zimmerman, D. J. Hughes, H. Palevsky, M. K. Brussel, and R. E. Chrien, Phys. Rev. **110**, 1472 (1958).

[3] C. Corge, V.-D. Huynh, J. Julien, S. Mirza, F. Netter, and J. Simic, Compt. rend. **249**, 413 (1959).

[4] C. Corge, V.-D. Huynh, J. Julien, J. Morgenstern, and F. Netter, J. phys. radium **22**, 724 (1961).

[5] L. M. Bollinger and R. E. Cote, Bull. Am. Phys. Soc. **5**, 294 (1961).

[6] J. R. Bird and J. R. Waters, Nuclear Phys. **14**, 212 (1959).

[7] H. E. Jackson and L. M. Bollinger, Phys. Rev. **124**, 1142 (1961).

[8] D. J. Hughes, M. K. Brussel, J. D. Fox, and R. L. Zimmerman, Phys. Rev. Letters **2**, 505 (1959).

[9] T. J. Kennett, L. M. Bollinger, and R. T. Carpenter, Phys. Rev. Letters **1**, 76 (1958).

[10] L. M. Bollinger, R. E. Cote, and T. J. Kennett, Phys. Rev. Letters **3**, 376 (1959).

[11] L. M. Bollinger, R. E. Cote, and J. P. Marion, Bull. Am. Phys. Soc. **6**, 274 (1961).

[12] D. J. Hughes, H. Palevsky, H. H. Bolotin, and R. E. Chrien, *Proceedings of the International Conference on Nuclear Structure, Kingston* (University of Toronto Press, Toronto, 1960), p. 772.

[13] C. Corge, V.-D. Huynh, J. Julien, J. Morgenstern, and F. Netter, J. phys. radium **22**, 722 (1961).

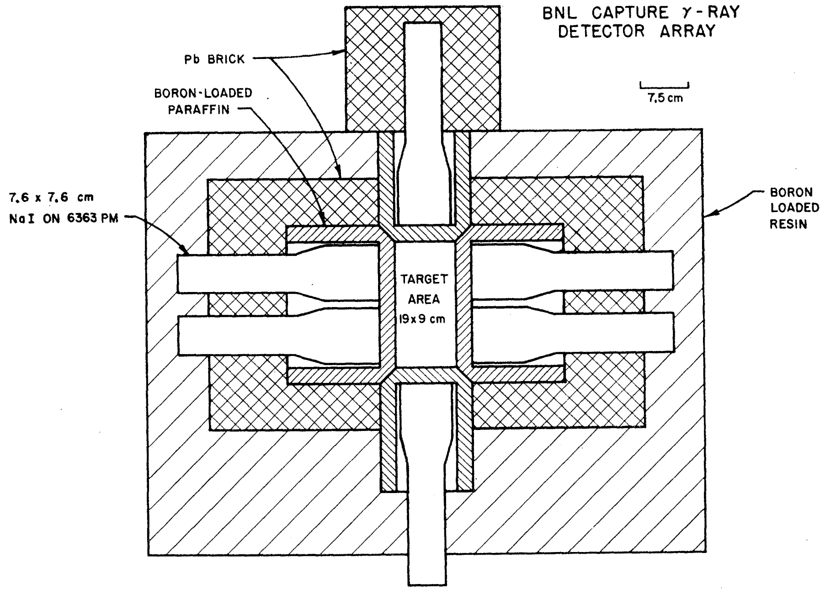


FIG. 1. A diagrammatic cross section of the BNL resonance capture γ-ray spectrometer.

levels which are intrinsically similar (e.g., members of the same rotational band) might show complete correlation.[14] For this reason, the crude pulse-height resolution then available was thought sufficient to permit judgments on the distributions of these composite partial widths. It was on the basis of such measurements that distributions of widths for W^{183} and U^{238} were analyzed.[8,12] More refined techniques later showed that these theoretical expectations are not justified and that it is, therefore, necessary to be able to separate closely spaced transitions.[10]

To form judgments on the variation of partial radiation widths, the sample chosen should fulfill the following requirements:

1. The sample should display numerous resonances, so as to give a large statistical sample.
2. The resonances must be well enough separated in energy to allow unambiguous isolation of the capturing state.
3. The spins and parities of the final states and the capturing states should be known.
4. The final states be well separated in energy so that a decomposition of the complex spectra obtained with a sodium iodide crystal be possible.
5. The sample size must be large, $\sim$100 g, which restricts samples to those which are abundantly occurring in nature. Platinum satisfies most, but not all, of these requirements. The level structure of Pt^{196} is favorable in that the states near ground are widely spaced and have known spins and parities. The spins of many of the capturing states are known, and the neutron resonances are fairly well separated. Finally, a large sample may be obtained.

[14] C. E. Porter and R. G. Thomas, Phys. Rev. **104**, 483 (1956).

The purpose of the present paper is to report recent work on resonance capture γ-rays due to the isotope Pt^{195} in a platinum target. The high-energy portions of spectra from 15 resonances have been recorded; of these, 12 resonances are assigned $J=1$ and, with the aid of a systematic unfolding program, the relative strengths of the three high-energy γ-rays above 7 MeV have been determined. The size distribution of the 36 transition probabilities has been fitted in terms of the chi-squared class of probability functions. A test for the statistical independence of these transitions has been applied by studying the distribution of the sum of the three transitions for these resonances.

EXPERIMENTAL ARRANGEMENT

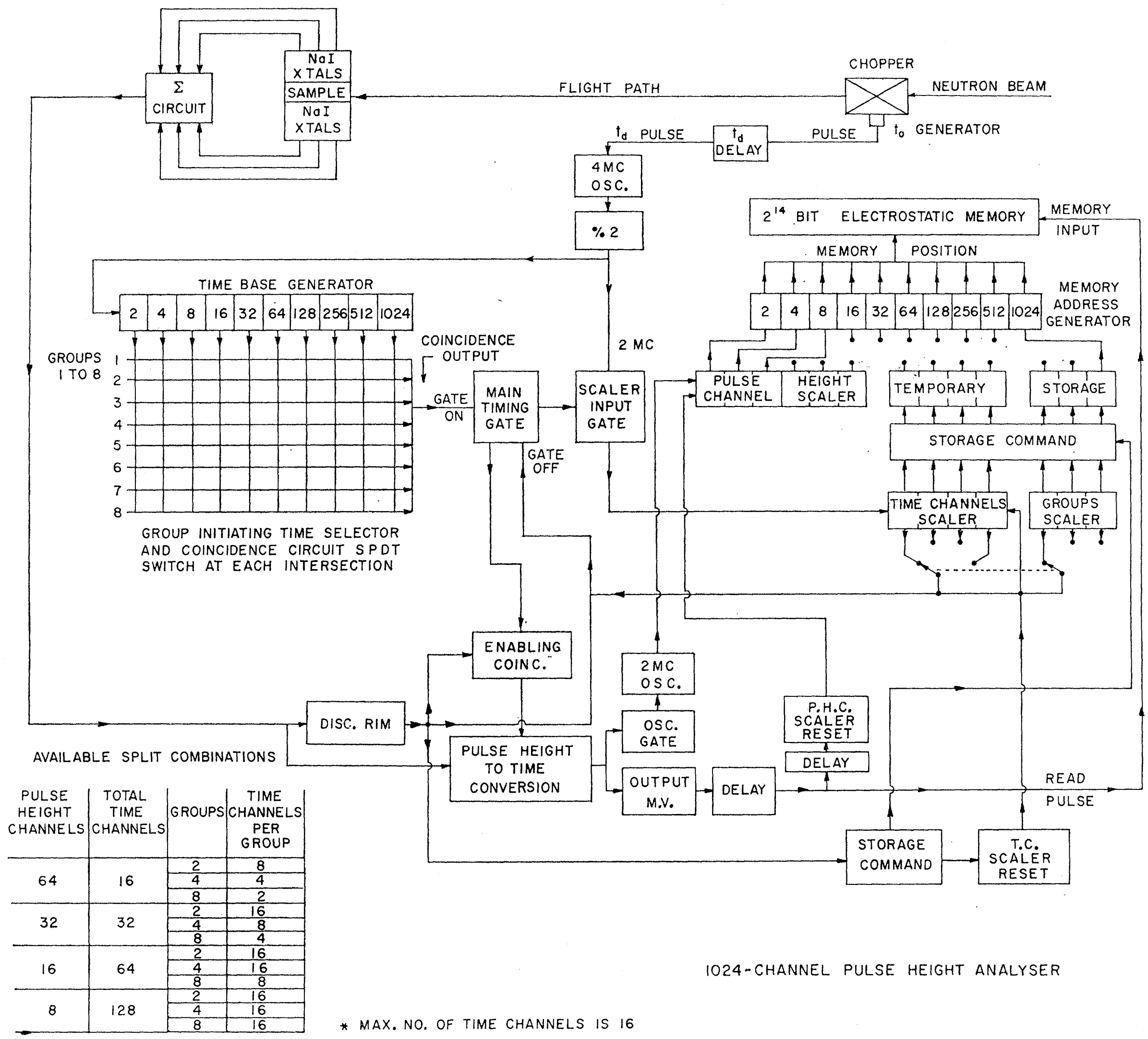
The present work was carried out at the joint BNL-AECL fast chopper project at Chalk River, Canada. This facility has been described in detail in an earlier publication.[15] The rotor is identical to the one which has been in operation at the Brookhaven Graphite Research reactor for the past several years.[16]

For partial cross-section work at this facility a 17-m flight path is normally used. The resulting resolution is about 70 nsec/n, which permits the study of perhaps a dozen resonances in a typical nuclide in the medium to heavy mass region.

The capture γ-ray detector, shown diagrammatically in Fig. 1, is a shielded array of six 3×3 in. NaI crystals mounted on Dumont 6363 photomultiplier tubes. Each detector is shielded from neutrons scattered by the target by 1 in. of boron-loaded paraffin. Further, lead

[15] R. L. Zimmerman, H. Palevsky, R. E. Chrien, W. C. Olsen, P. P. Singh, and C. H. Westcott, Nuclear Instr. and Methods **13**, 1 (1961).

[16] F. G. P. Seidl, H. Palevsky, D. J. Hughes, and R. L. Zimmerman, Nuclear Instr. and Methods **1**, 92 (1957).



PULSE HEIGHT CHANNELS	TOTAL TIME CHANNELS	GROUPS	TIME CHANNELS PER GROUP
64	16	2	8
		4	4
		8	2
32	32	2	16
		4	8
		8	4
16	64	2	16
		4	16
		8	8
8	128	2	16
		4	16
		8	16

FIG. 2. Block diagram of the multi-dimensional analyzer for simultaneous pulse height and time-of-flight recording.

shielding is provided around each tube to lower the pile γ-ray background and cosmic-ray background. The detector array is further covered by an outer shielding of resin blocks loaded with lead oxide and boric oxide (77.2% PbO, 17.7% resin, and 6% B_2O_3 by weight). The detector array is preceded by a lead collimator which prevents the beam from striking the walls defining the target area, which is 9×19 cm. The collimation down to this size allows the use of only one-half of the neutron beam current from the chopper. The total solid angle subtended by the six detectors is about 10%, and the over-all efficiency for 8-MeV γ rays is about 3%. To give maximum counting rates, thick samples, which absorb most of the neutrons, are used. The self absorption of γ rays is not important for this experiment. Although low-energy γ rays are absorbed in the target, this absorption will be the same from resonance to resonance and will not affect relative measurements. In this experiment the sample was composed of several platinum "pies" fitted together to give a target thickness of about 1/2 in. over the target area.

The phototubes are run at low gain—only 700 V are applied between photocathode and last dynode. To maintain good resolution, the potential between photocathode and first dynode is 200 V or more. This mode of operation minimizes gain drift, which is normally well below 1% for a 24-h period. Individual high-voltage adjustment on the tubes permits accurate gain matching of the array.

The mixing of signals from the six detectors is done by a nonadditive mixer patterned after a circuit described by Valley and Wallman.[17] The purpose of the mixer in this experiment is to suppress the summing of pulses arising from the simultaneous detection of

[17] G. E. Valley and H. Wallman, *Vacuum Tube Amplifiers* (McGraw-Hill Book Company, Inc., New York, 1948).

several members of a γ-ray cascade in the separate detectors. The accidental summing could result in a spurious pulse simultaing a high-energy γ ray. This device selects only the largest of several coincident pulses from the detectors and suppresses the rest.

The Brookhaven 1024-channel analyzer with electrostatic memory has been modified by the addition of a transistorized pulse-height analyzer to permit simultaneous determination of pulse height and time-of-arrival. A block diagram of the circuitry of this multidimensional analyzer is shown in Fig. 2. For a description of the analyzer operation reference 15 may be consulted. There is considerable flexibility in the division of analyzer memory between pulse height and time. Figure 3 shows an example of platinum raw data as recorded with this analyzer. For this particular run 16 pulse-height channels were used, with 64 consecutive time channels of 0.5 μsec each. Many other combinations are possible up to a maximum of 64 pulse-height channels. For the present work, however, 16 pulse-height channels were employed.

The response of the detectors to a single γ ray has been deduced from the examination of standard sources (such as the C^{12} γ ray from a PuBe neutron source) and of thermal capture γ-ray spectra. Figure 4 shows the response of the array to the 7.73-MeV line resulting from thermal neutron capture in aluminum. The curve shown is obtained after background subtraction (obtained using a carbon target of equivalent neutron scattering thickness) and a small correction for weaker low-energy γ rays from aluminum. The full width at half-maximum for the full energy peak is 5% at 8 MeV and 6% at 4 MeV.

The principal sources of background depend upon the γ-ray energy region being examined. Below 2 MeV, the major background component arises from the transmission of pile γ rays through the chopper rotor. This background is a strong function of chopper angle, showing broad peaks at angles corresponding to regions of minimum opacity after the rotor is closed. At intermediate energies, 2–6 MeV, neutron capture γ rays in the shielding surrounding the detectors become dominant. These capture γ rays result mostly from neutrons scattered from the target. Above about 7 MeV, cosmic-ray background is important. In the experiment, background is determined by observing the resonance in neutron time-of-flight and using the time regions adjacent to the resonance as a measure of background.

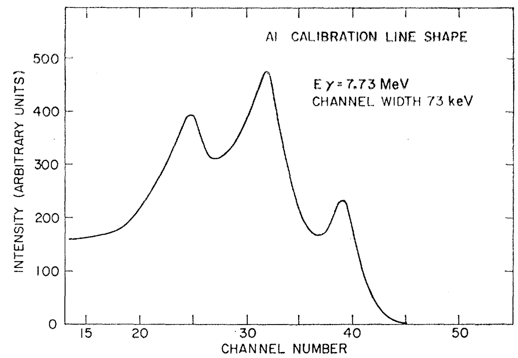


FIG. 4. The response of the 6 NaI detectors to the 7.73-MeV Al γ ray.

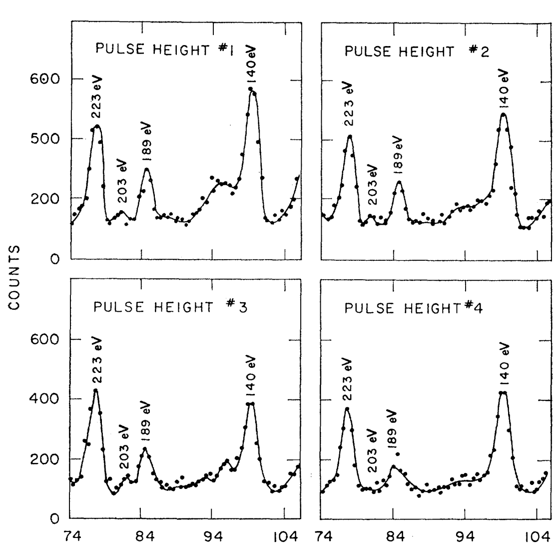


FIG. 3. A sample of Pt data from the analyzer showing four pulse-height cuts.

DATA ANALYSIS

The capture γ-ray pulse-height spectrum which is to be analyzed is obtained by determining areas under the resonances such as those shown in Fig. 3. The areas are

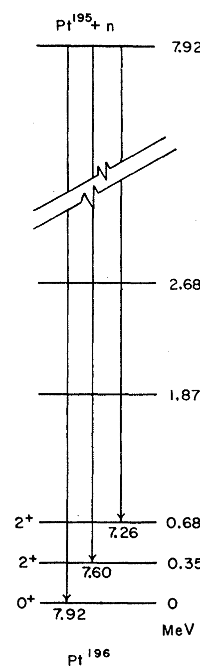


FIG. 5. The decay scheme for Pt^{196}.

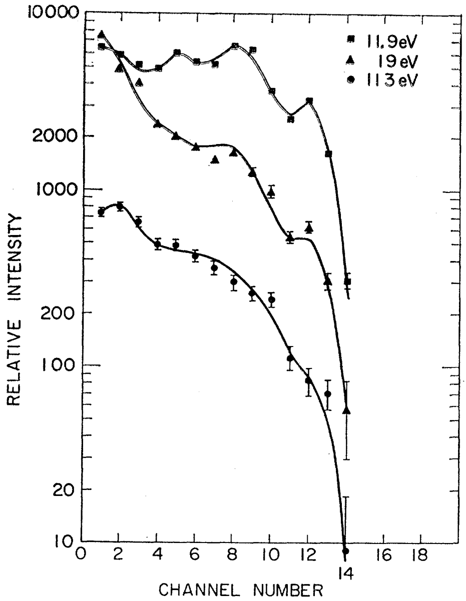


FIG. 6. Observed spectra in Pt^{196} at 11.9, 19, and 113 eV.

then plotted as a function of pulse height to obtain a pulse-height distribution. The major problem involved in determining the intensity of a single γ ray is the complex response of a typical NaI detector of limited size to monchromatic radiation. Only when the various component lines are reasonably well separated in energy, and their energies known *a priori*, can their relative intensities be determined with any accuracy. It is necessary to have some systematic method of decomposing the observed spectrum into its components. At Chalk River, use has been made of a curve-fitting program written by Ferguson,[18] which uses a polynomial expansion for the NaI response function. This program computes the spectrometer line shape at any energy by interpolation between supplied calibration lines for several γ-ray energies. The observed spectrum is then fitted by a least-squares procedure. The program supplies the intensity coefficient for each γ ray and its error along with a criterion for goodness of fit. This intensity coefficient is proportional to the number of photons of this particular energy emitted in the decay of the capturing state.

The calculation of transition probabilities is performed by dividing the intensity coefficients by the area of the resonance as observed in a suitably normalized "low bias" run. The "low bias" run is one in which all γ rays above some low energy limit—usually 2 MeV—are counted. The "low bias" areas are proportional to the total number of photons emitted in the decay. The ratio then represents the fraction of all decays taking place via this transition. The total radiation widths and the γ-ray multiplicity do not vary significantly from resonance to resonance.[19] We therefore interpret these ratios as relative transition probabilities.

[18] A. J. Ferguson, Atomic Energy of Canada, Limited, Report AECL-1398, 1962 (unpublished).

RESULTS

The relevant decay scheme for Pt^{196} is shown in Fig. 5.[20] We fix our attention on the observation of transitions from the 1^- capturing states in Pt^{196} to the 0^+ ground state and to the two 2^+ excited states. The 0^- capturing states are not expected to contribute strongly. The transitions show up clearly in the work of Groshev,[20] and the energies of these transitions are established as 7.92, 7.60, and 7.26 MeV. For each resonance, 16 pulse-height channels, each 146 keV wide, were used. The baseline was set at 6 MeV. Time channels from 1/2 to 2 μsec, depending on the energy of the resonance, were employed. The resulting pulse-height curves for 12 resonances from 11.9 to 300 eV are given in Figs. 6 through 9. The lines show the least-squares fits obtained from the program of Ferguson. The spectra are arbitrarily normalized for display purposes. It must be pointed out that in fitting these spectra two additional lines, not inconsistent with the spectrum presented by Groshev, were inserted at 6.2 and 6.4 MeV. These lines do not seriously affect the transition probabilities for the high-energy lines of interest, but are necessary to provide a good fit in the region from 6 to 6.5 MeV, which is in the neighborhood of the escape peaks of the 7.26-MeV γ-ray.

Table I gives the relative transition probabilities deduced for the three high-energy transitions. The probabilities have been normalized to unit mean for the

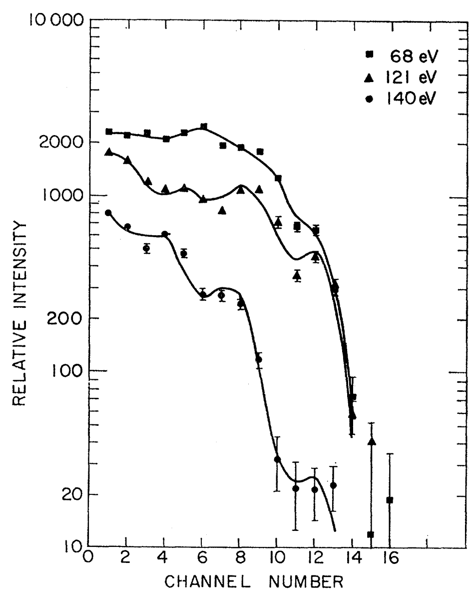


FIG. 7. Observed spectra in Pt^{196} at 68, 121, and 140 eV.

[19] T. E. Springer and J. E. Draper, Bull. Am. Phys. Soc. 4, 35 (1959).

[20] L. V. Groshev, A. M. Demidov, V. N. Lutsenko, and V. I. Pelekov, *γ-Ray Spectra from Radiative Capture by Slow Neutrons* (Pergamon Press, New York, 1959).

TABLE I. Pt^{196} transition probabilities.

Level (eV)	7.92-MeV transition	7.6-MeV transition	7.26-MeV transition	Sum
11.9	2.84 ±0.12	0.43 ±0.27	<0.24	3.33 ±0.21
19	0.57 ±0.12	0.28 ±0.18	0.62 ±0.18	1.69 ±0.16
68	1.83 ±0.14	2.14 ±0.22	0.26 ±0.22	4.59 ±0.19
113	0.62 ±0.10	0.85 ±0.17	0.62 ±0.18	2.39 ±0.15
121	1.48 ±0.14	0.30 ±0.22	0.18 ±0.18	2.05 ±0.18
140	0.28 ±0.09	0.09 ±0.14	2.85 ±0.21	4.08 ±0.15
152	0.29 ±0.12	0.28 ±0.22	0.53 ±0.27	1.29 ±0.20
189	1.02 ±0.16	0.43 ±0.27	0.98 ±0.27	2.78 ±0.23
223	1.39 ±0.32	3.65 ±0.66	1.75 ±0.71	7.79 ±0.57
252	0.04 ±0.12	0.18 ±0.16	0.56 ±0.19	0.97 ±0.15
277	1.60 ±0.29	0.22 ±0.57	0.22 ±0.41	2.13 ±0.44
296	0.03 ±0.08	1.87 ±0.19	0.11 ±0.21	2.29 ±0.16
Mean	1.000±0.048	0.893±0.091	0.723±0.088	2.948±0.077

7.92-MeV set. The mean values for the 7.6-MeV and 7.26 MeV sets grow progressively smaller. This fact will be discussed later. The table also shows the relative transition probabilities for the sum of three transitions from each resonance, after correction for an assumed E^3 dependence of the transition probabilities.

With the available time-of-flight resolution, it proved to be feasible to examine 15 resonances due to Pt^{195} plus neutron. These are located at the following energies: 11.9, 19, 68 (2 resonances), 113, 121, 140, 152, 155, 189, 203, 223, 252, 277, and 296 eV. Since the main interest in the present work lies in the distribution of transition probabilities, it is important to obtain a statistically unbiased sample of resonances. We now examine this requirement in some detail.

The isotopic indentifications of the neutron resonances in platinum have been made by conventional transmission measurements on separated isotopes and by capture γ-ray studies.[3,7,21] The 15 resonances listed

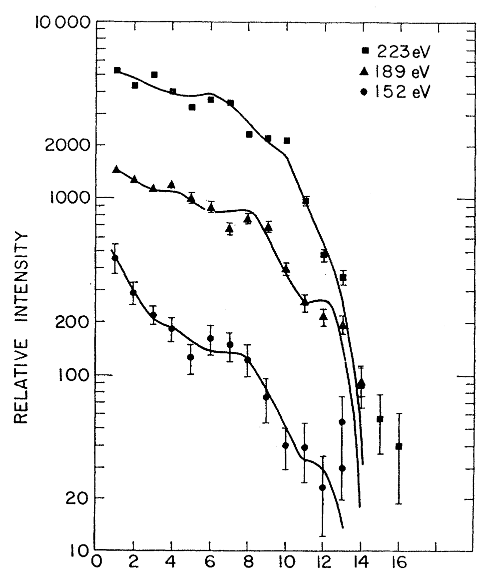


FIG. 8. Observed spectra in Pt^{196} at 223, 189, and 152 eV.

[21] D. J. Hughes, B. Magurno, and M. K. Brussel, *Neutron Cross Sections*, Brookhaven National Laboratory Report BNL-325 (U. S. Government Printing Office, Washington, D. C., 1960), 2nd ed., Suppl. No. 1.

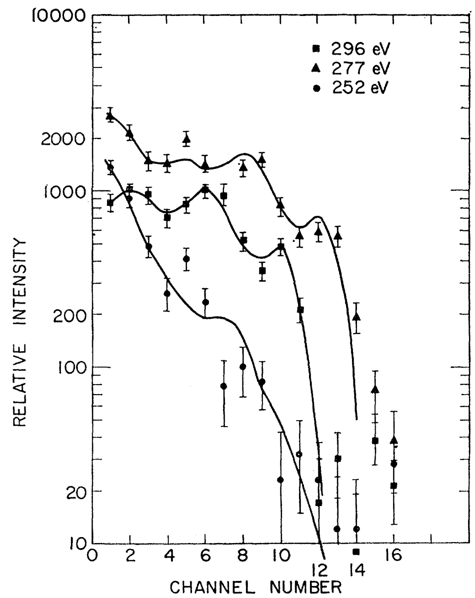


FIG. 9. Observed spectra in Pt^{196} at 296, 277, and 252 eV.

above may not include all the Pt^{195} resonances present up to 300 eV since resonances with very small neutron widths are likely to be missed due to limited instrumental resolution. There is, however, no evidence of correlation between neutron widths and radiation widths, and we, therefore, conclude that the exclusion of one or more levels with very small *neutron* widths does not introduce a bias in the selection of partial *radiation* widths.

There is a more serious difficulty in the assignment of the angular momentum of the capturing state. A table of spin assignments made from scattering data and capture γ-ray data for several resonances in platinum may be found in the review article by Bartholomew.[1] It is clear that the observation of a γ ray corresponding to a transition from the capturing state (1^- or 0^-) to the ground state (0^+) of Pt^{196} establishes the spin and parity of the capturing state as 1^-. The argument is almost as strong for the observation of transitions to the 2^+ excited states, since $M2$ primary radiation is so weak as to be unobservable with present detection efficiencies. Failure to observe a γ ray *may* be ascribed to a 0^- capturing state, but the possibility of an $E1$ transition strength below the level of instrumental detectability cannot be ruled out. In the present case, we have measured three transitions from each capturing state, and it is not probable that all three transitions from a 1^- capturing state be simultaneously so weak as to be undetectable. We have made the assignment $J=0$, therefore, when all three transition strengths are statistically consistent with zero. We find that this is the case for the resonance at 203 eV. (See Table I.) The ground and first excited state transitions of the 252-eV level are statistically consistent with zero. However, the spectrum (Fig. 9) clearly exhibits a transition of moderate

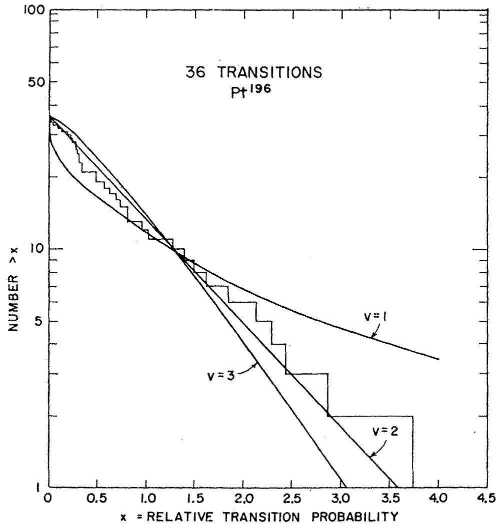


FIG. 10. Cumulative size distribution of 36 transitions in Pt^{196}. Theoretical curves for chi-squared distributions with $\nu=1$, 2, and 3, are also shown. Resonances at 66.9, 155, and 203 eV have been assigned $J=0$ and are not listed here.

strength to the second excited 2^+ level and we have, therefore, assigned a spin of $J=1$ for this level. An assignment of $J=0$ would imply an $M2$ transition and this seems unlikely because, on the average, an $M2$ transition is on the order of 1000 times weaker than an $E1$ transition of the same energy.

Several known resonances in Pt^{195} are not well enough resolved in the present experiment to permit spin determination by the above technique. These are resonances at 66.9 and 67.4 eV reported by Argonne[7,22] and Saclay,[3] and resonances at 151 and 155 eV reported by Saclay[3] and Oak Ridge.[23] Because of the known "repulsion" of levels of like spin, it does not seem likely that both members of each pair have $J=1$. We may formulate this idea quantitatively by considering the Wigner distribution of level spacings:

$$P(S)=\pi S/2D^2 \exp(-\pi S^2/4D^2),$$

where D is the average level spacing.[24] For $J=1$ levels of Pt^{195} $D\approx 20$ eV; $S\approx 0.5$ eV for the pair near 68 eV and $S\approx 4$ eV for the pair near 152 eV. Assuming $J=1$ for all levels, the probability of the former pair having the observed spacing or less is 0.05%, and for the latter it is only 3.1%. We have, therefore, assigned $J=0$ levels at 66.9 and at 155 eV.

The resulting sampling of levels has 12 $J=1$ levels and three with $J=0$, which is compatible with a $2J+1$ dependence in the level density formula. The binomial distribution assigns a probability of only 23.6% to the possibility of having fewer than three $J=0$ levels.

[22] G. E. Thomas, Argonne National Laboratory Report ANL-6072, 1959 (unpublished).

[23] J. A. Harvey, Bull. Am. Phys. Soc. 4, 473 (1959).

[24] M. L. Mehta, *Proceedings of the International Conference on Nuclear Structure* (University of Toronto Press, Toronto, 1960), p. 776.

DISCUSSION OF RESULTS

The table of transition probabilities shows successively a smaller average for the lower energy lines. According to the usual Weisskopf estimates based on an independent particle model, these transitions should show an E^{2l+1} behavior.[25] Since it is assumed here that only electric dipole transitions contribute significantly to the detected radiation, we would expect an E^3 variation in the strengths of these transitions. Recently, however, Axel[26] has argued that a variation of E^5 near 7 MeV should be expected because of the grouping of single-particle states of high strengths implied by the presence of the giant dipole resonance near 20 MeV. We have assumed, for the analysis of the results of this experiment, that the transition strengths vary as E^3.

If the results of this table are normalized by the E^3 factor to the ground-state energy, there are effectively 36 transitions that can be considered. It is customary in the discussion of fluctuations in reaction widths to describe them in terms of the chi-squared class of probability distributions[14]:

$$P(x,\nu)dx=[\Gamma(\nu/2)]^{-1}(\nu x/2)^{\nu/2-1}(\nu/2)[\exp(\nu x/2)]dx.$$

The number of exit channels associated with the reaction is to be associated with the number of degrees of freedom ν of the distribution. The broadness of the distribution increases with decreasing ν. Neutron widths (reduced to equivalent neutron energy) have been shown to follow a $\nu=1$ or Porter-Thomas distribution.[14] The fission process evidently possesses several discrete exit channels and the corresponding fission widths obey chi-squared distributions with 2 or 3 deg of freedom. The justification for the use of the chi-squared family of distributions in analysis of reaction widths rests on a plausibility argument outlined by Porter and Thomas and has not been given a firm theoretical basis. However, the family of distributions is so general as to be useful for descriptive purposes, even if a firm justification does not exist.

It is of interest then to examine the distribution of 36 partial radiation widths in terms of this class of probability distributions. The method of maximum likelihood as outlined by Porter and Thomas has been applied to the data. The effects of experimental errors have been included in the analysis. The best value for ν, the number of degrees of freedom, is found to be $\nu=2.0^{+0.8}_{-0.4}$. The cumulative probability distribution is shown in Fig. 10. For purposes of comparison the curves for $\nu=1$, 2, and 3 are shown.

The previous discussion concerning spin assignments indicates we must allow for a possible systematic error due to assigning $J=0$ to a level with three weak $J=1$ transitions. Accordingly, we have calculated the effects

[25] J. M. Blatt and V. Weisskopf, *Theoretical Nuclear Physics* (John Wiley & Sons, Inc., New York, 1952).

[26] P. Axel, Technical Report No. 30, Physics Research Laboratory, Physics Department, University of Illinois, 1961 (unpublished).

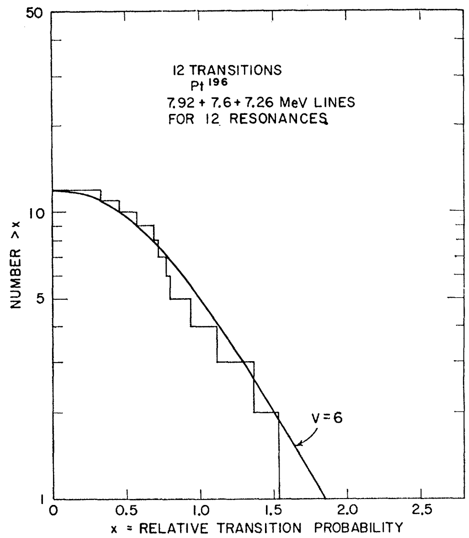


FIG. 11. The cumulative size distribution for the sum of the three high-energy transitions in Pt^{196}. The curve is for $\nu=6$.

of assigning $J=1$ to the level at 155 eV. The best value of ν in this case is lowered to 1.7. We conclude that the number of degrees of freedom describing the distribution in size of radiative transitions in Pt^{196} is quite small, lying between 1 and 2. The best fit to the observed distribution in strengths, however, is obtained with an exponential ($\nu=2$) rather than with a Porter-Thomas ($\nu=1$) distribution.

It is also of interest to examine the distribution of the sum of these three transitions. The narrowness of the distributions[3,8,12] of transitions to the unresolved low-lying states in U^{239} and W^{184} may be explained by postulating that the individual transitions are not independent. In Pt^{196} we find that the sum distribution has $\nu=6.2_{-2.5}^{+2.8}$ (this is decreased to $\nu\cong 5$ with the inclusion of $J=1$ for the 155-eV level). The fit to $\nu=6$ is shown in Fig. 11. For the combination of independent chi-squared distributions, the number of degrees of freedom is additive. We conclude, therefore, that in Pt^{196} we find no evidence for correlations between the transitions to the 0^+ ground state and the 2^+ excited states at 354 and 686 keV.

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Direct Observation of Resonant *p*-Wave Neutron Capture*

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The capture γ-ray spectra of resonances in Mo^{95} below 700 eV have been studied in an effort to make unambiguous identification of individual resonances resulting from capture of *p*-wave neutrons. A discussion is presented of the features of the experimental spectra which can be used to identify the parity of the compound state formed by neutron capture. In particular, a resonance in Mo^{95} at 107 eV with an anomalously strong ground-state transition is observed. The strength of this line is inconsistent with *s*-wave capture. The resonance must be due to capture of a *p*-wave neutron; the transition must be $E1$; and the capture state must be 1^-.

I. INTRODUCTION

THE study of the interactions of *p*-wave neutrons has received strong emphasis in neutron spectroscopy recently, particularly in the mass region around $A=90$ where the optical model predicts a giant resonance in the *p*-wave neutron strength function $\langle\Gamma_n^1\rangle/D$. The presence of *p*-wave neutron resonances in this region has been established by studying the distribution of reduced resonance widths $g\Gamma_n^0$ over some restricted range of energies below 1 keV,[1,2] and noting a number of levels, presumably *p*-wave resonances, with small $g\Gamma_n^0$ in excess of the amount predicted by a Porter-Thomas distribution. However, because of the character of the distribution, a unique separation of resonances of opposite parity is not possible. To date, no resonance below 20 keV has been specifically identified as being due to *p*-wave capture.

There are two reasons why the unambiguous identification of *p*-wave capture is of particular interest. First, although there has been conjecture as to the dependence of resonance parameters (particularly the total radiation width[3]) on the parity of the capture state, no experimental observations have been made for lack of known *p*-wave resonances. The second

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