Coulomb excitation of 2^+ and 3^- states in ^{192}Pt and ^{194}Pt

R. M. Ronningen, R. B. Piercey, A. V. Ramayya, and J. H. Hamilton
Physics Department, Vanderbilt University, Nashville, Tennessee 37235*

S. Raman, P. H. Stelson, and W. K. Dagenhart
Physics Division, Oak Ridge National Laboratory,† Oak Ridge, Tennessee 37830

(Received 12 April 1977)

Coulomb excitation of ^{192,194}Pt, by 14.9 MeV α particles was studied by the magnetic analysis of the particles scattered into 150°. For ^{192}Pt, $B(E2;0^+ \rightarrow 2^+)$ values to the 2^+ states at 317 and 612 keV are 1.89 ± 0.03 e^2 b^2 and 0.013 ± 0.002 e^2 b^2, respectively. For ^{194}Pt, the $B(E2)\uparrow$ values to the 2^+ states at 329 and 633 keV are 1.68 ± 0.03 e^2 b^2 and 0.0094 ± 0.0015 e^2 b^2, respectively. States with $J^\pi = 3^-$ at 1378 keV in ^{192}Pt and 1432 in ^{194}Pt are also excited, with $B(E3)\uparrow$ values of 0.17 ± 0.03 e^2 b^3 and 0.14 ± 0.03 e^2 b^3, respectively. We compare our measurements to others.

[NUCLEAR REACTIONS ^{192,194}Pt(α,α'), E=14.9; measured Coulomb excitation. ^{192,194}Pt levels deduced $B(E2)$, $B(E3)$. Enriched targets.]

I. INTRODUCTION

There has always been interest in transitional nuclei and recently the Pt isotopes have become the subjects of much experimentation. For example, the high spin level spacings in $^{190-194}$Pt have been mapped out by heavy ion reactions[1-3] with the rotation-alignment model[4] invoked to explain[1-3,5] the anomalous level behaviors. Also, Coulomb-nuclear interferences in the excitation of ^{194}Pt have been studied[6] to yield relative phases as well as magnitudes of transition matrix elements connecting the ground state and the first two $J^\pi = 2^+$ states.

The establishment of accurate $B(E2)$ and $B(E3)$ values is important not only for the proper interpretation of such experiments but also for the evalua-

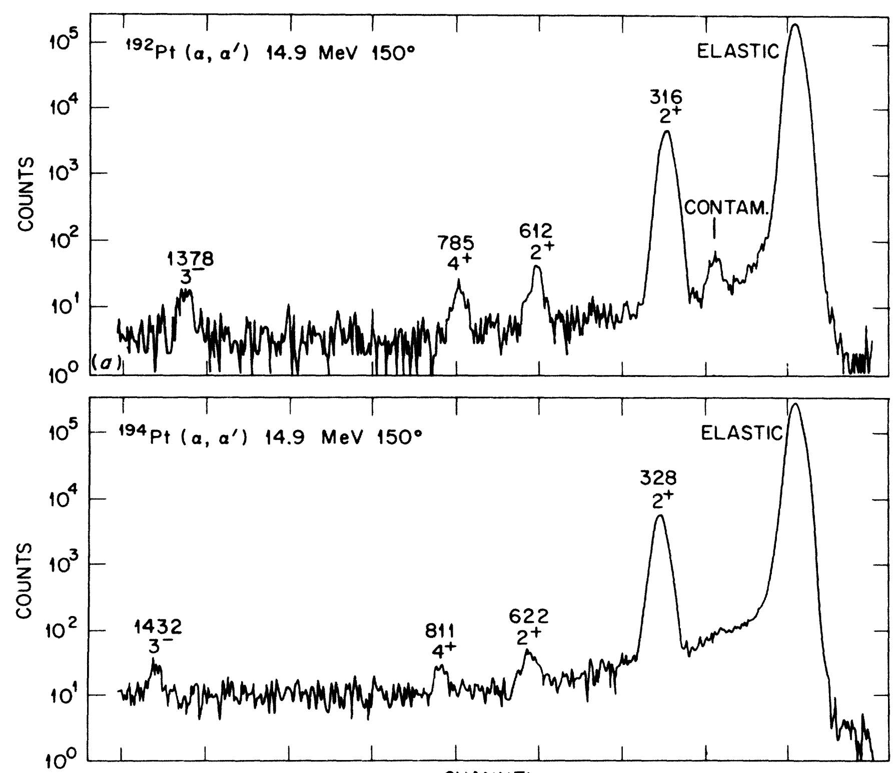

FIG. 1. Spectrum of elastically and inelastically scattered 14.9 MeV α particles from ^{192}Pt and from ^{194}Pt. The peaks are labelled with level energies in keV.

tion of theories which predict these values. The preparation of a compilation[7] of $B(E2;\ 0^+ \rightarrow 2_1^+)$ values has revealed a 13% discrepancy between reported measurements[8,9] for ^{194}Pt. One of these was part of a systematic study of W, Os and Pt nuclei by Coulomb excitation performed earlier[8] at the Oak Ridge National Laboratory (ORNL).

In this work, we have obtained precise values of $B(E2;\ 0^+ \rightarrow 2_1^+)$ for both ^{192}Pt and ^{194}Pt by employing the magnetic-spectrographic analysis of ^{4}He ions, scattered after Coulomb excitation from thin targets of high purity. We have recently given[10] a preliminary report of this study.

II. EXPERIMENTAL PROCEDURE AND ANALYSIS

The Coulomb excitation of ^{192,194}Pt, by 14.9 MeV ^{4}He ions from the ORNL tandem Van de Graaff accelerator scattered through 150°, was studied using an Enge split-pole spectrograph and a 60 cm long, position-sensitive, gas-flow proportional counter. Our targets were ≈30 μg/cm² separated material of >99% isotopic purity deposited on 65 μg/cm² carbon foil backings.

Fig. 1 shows the spectra of scattered α particles for ^{192,194}Pt. A contaminant peak was observed between the elastic and 2_1^+ peaks. It appears most noticeably in the spectrum for ^{192}Pt but weakly in the spectrum for ^{194}Pt. The intensity of this peak in the ^{192}Pt spectrum is about 1% of the intensity of the first 2^+ state in ^{192}Pt. A possible candidate for it would be a state in another Pt isotope. An unresolved 211-239 keV doublet in ^{195}Pt could be responsible. However, we do not regard this as a very likely explanation since there would be only one mass unit difference for the ^{194}Pt target and this peak should appear more strongly in the spectrum for ^{194}Pt rather than ^{192}Pt. A more likely candidate for this peak would be the elastic peak of a heavy isotope passing through the isotope separator as a complex ion, such as ^{181}Ta + ^{12}C.

Experimental ratios of inelastic-to-elastic scattering differential cross sections were compared to ratios calculated with the aid of both semiclassical (de Boer-Winther[11]) and quantal (AROSA[12]) Coulomb excitation codes. Quantal corrections decreased the calculated ratios for 2_1^+ excitation by ≈0.4% and increased the ratios for the 2_2^+ state by ≈6.4%. Our previously reported results[10] were analyzed with the semiclassical code only. Matrix elements, $M_{J_iJ_f}$, and their signs, connecting the 0^+, 2_1^+, 2_2^+ and 4^+ were initially taken from previous studies[5,6,8,13] or from oblate model predictions. However, a preliminary report on ^{194}Pt by Baktash *et al.*[14] notes the large value of $M_{2_12_2}$ relative to M_{02_2}. To study

Table 1. Summary of Results

Nucleus	E (level)[a] (keV)	J^π	Present study $B(E\lambda)\uparrow$ (e^2b^λ)[b]	Other measurements $B(E2)\uparrow$ (e^2b^2)	Method[c]	Ref.
^{192}Pt	316.5	2_1^+	1.89 ± 0.03		*CXI*	
				1.70 ± 0.10	*DSRD*	5
				2.10 ± 0.12	*CXG*	8
				2.28 ± 0.27	*CXG*	13
				2.00 ± 0.04	*CXG*	19
	612.5	2_2^+	0.013 ± 0.002		*CXI*	
				0.020 ± 0.003	*CXG*	19
				0.025 ± 0.0025	*DC*	20
				0.0235 ± 0.0025	*DC*	21
	1378.2	3_1^-	0.17 ± 0.03		*CXI*	
^{194}Pt	328.5	2_1^+	1.68 ± 0.03		*CXI*	
				1.55 ± 0.10	*DSRD*	5
				1.67 ± 0.13	*CXI*	6
				1.87 ± 0.09	*CXG*	8
				1.64 ± 0.04	*CXI*	9
	622.1	2_2^+	0.0094 ± 0.0015		*CXI*	
				0.013 ± 0.002	*CXG*	19
				0.0075 ± 0.0010	*DC*	21
	1432.4	3_1^-	0.14 ± 0.03		*CXI*	

[a]Level energies are from M. R. Schmorak, A = 192, Nucl. Data Sheets 9, 195 (1973) and R. L. Auble, A = 194, Nucl. Data Sheets 7, 95 (1972).
[b]$\lambda = 2$ for 2^+ states and $\lambda = 3$ for 3^- states.
[c]Coulomb excitation studied by detecting inelastically scattered particles *(CXI)* or γ rays *(CXG)*. *DC* denotes delayed coincidence lifetime measurements, and *DSRD* denotes the Doppler-shift recoil-distance technique.

this effect, the $2_2 \rightarrow 2_1/2_2 \rightarrow 0$ branching ratios were obtained from γ-ray intensities from Ir-to-Pt decays.[15] These ratios were corrected for *M1* admixtures by using $\delta = 5.4 \pm 0.2$ for ^{192}Pt (Ref. 16), and $\delta = 14.3 \pm 2.1$ for ^{194}Pt (Ref. 17). The *B(E2)* ratios thus have the values of 194.1 ± 4.4 and 305 ± 34 for ^{192,194}Pt, respectively. The sign of the matrix element $M_{02_1}M_{2_12_2}M_{02_2}$ was kept negative as experimentally found for ^{194}Pt by Baker *et al.*[6] The negative sign for this product in the case of ^{192}Pt has also been recently confirmed through measurements.[18]

Our final *B(E2)* values for the 2_1^+ states are thus ∿3% larger than values obtained from employing only M_{02} matrix elements. The *B(E2)* values for the 2_2^+ states are decreased by ∿50%. An uncertainty in our analysis of the ^{192}Pt data is that the static *E*2 moment of the 2_1^+ state has not been measured. A value for it was estimated by scaling the static moment of ^{194}Pt, which has been measured by Grodzins *et al.*[13] by the ratio $(M_{02_1})_{192}/(M_{02_1})_{194}$.

III. RESULTS AND DISCUSSION

Table 1 summarizes values from direct measurements of *B(E2)* to the first 2^+ states in ^{192,194}Pt, and includes values from direct and indirect measurements of *B(E2)* to the second 2^+ states.

Besides the earlier work of Grodzins *et al.*,[13] only Milner *et al.*[8] have measured absolute *B(E2)* values for both ^{192}Pt and ^{194}Pt from γ-ray yields following Coulomb excitation. Bruton *et al.*[19] have studied both but normalize their measurements separately to Milner *et al.*[8] and also to Glenn *et al.*[9] A magnetic spectrograph was employed by Glenn *et al.*[9] to study scattered α particles after Coulomb excitation of ^{194}Pt. Our values for the first 2^+ states in ^{192,194}Pt are smaller than most of the previous measurements although we are in good agreement with Glenn *et al.*[9] and Baker *et al.*[6] for ^{194}Pt. We also obtain the same ratio of *B(E2)* values for ^{192}Pt to ^{194}Pt as would Milner *et al.*[8] Our lower values for ^{192,194}Pt have been very recently supported by the mean life measurements by Johnson *et al.*[5] using the recoil distance technique. They extract *B(E2)* values of 1.55 ± 0.10 and 1.70 ± 0.10 e^2b^2 for ^{192,194}Pt, respectively.

For higher lying 2^+ states we are in good agreement with Berkes *et al.*[21] for ^{194}Pt only.

States with $J^\pi = 3^-$ at 1378 keV in ^{192}Pt (Ref. 22) and 1432 keV in ^{194}Pt (Ref. 23) were observed in our study to have *B(E3)* values of 0.17 ± 0.03 and 0.14 ± 0.03 e^2b^3, respectively. Their collective strengths, 11 ± 2 and 8 ± 2 single particle units, suggest an octupole vibrational nature.

In conclusion, our study indicates smaller *B(E2)* values to the 2^+ states than most previous measurements for both ^{192,194}Pt. Such data should be of interest not only to experimentalists needing precise values to interpret their experiments but to theorists as well. Our *B(E2)* values for ^{192,194}Pt are in good agreement with Kumar's[24] pairing plus-quadrupole model calculations, these being 1.82 e^2b^2 and 1.71 e^2b^2 for ^{192,194}Pt, respectively.

We acknowledge helpful discussions with Noah R. Johnson, S. W. Yates and F. Todd Baker.

---

*Research supported in part by a grant from the U. S. Energy Research and Development Administration (ERDA).

†Research sponsored by the U. S. ERDA under contract with the Union Carbide Corporation.

[1] L. Funke, P. Kemmitz, G. Winter, S. S. Hjorth, A. Johnson and Th. Lindblad, Phys. Lett. 55B, 436 (1975).
[2] J. C. Cunnane, M. Piiparinen, P. J. Daly, C. L. Dors, T. L. Khoo and F. M. Bernthal, Phys. Rev. C 13, 2197 (1976).
[3] S. S. Hjorth, A. Johnson, Th. Lindblad, L. Funke, P. Kemmitz and G. Winter, Nucl. Phys. A262, 328 (1976).
[4] F. S. Stephens and R. S. Simon, Nucl. Phys. A183, 257 (1972).
[5] Noah R. Johnson, P. P. Hubert, E. Eichler, D. G. Sarantites, J. Urbon, S. W. Yates and Thomas Lindlad, Phys. Rev. C 15, 1325 (1977).
[6] F. Todd Baker, Alan Scott, T. H. Kruse, W. Hartwig, E. Ventura and W. Savin, Phys. Rev. Lett. 37, 193 (1976); F. Todd Baker, private communication.
[7] S. Raman, P. H. Stelson and W. T. Milner, Atomic Data and Nuclear Data Tables (unpublished).
[8] W. T. Milner, F. K. McGowan, R. L. Robinson, P. H. Stelson and R. O. Sayer, Nucl. Phys. A177, 1 (1971).
[9] J. E. Glenn, R. J. Pryor and J. X. Saladin, Phys. Rev. 188, 1905 (1969).
[10] R. M. Ronningen, R. B. Piercey, A. V. Ramayya, J. H. Hamilton, W. K. Dagenhart, S. Raman and P. H. Stelson, Bull. Am. Phys. Soc. 21, 976 (1976).
[11] A. Winther and J. de Boer, *Coulomb Excitation*, edited by K. Alder and A. Winther (Academic Press, New York, 1966) p. 303.
[12] F. Roesel, J. X. Saladin and K. Alder, Comput. Phys. Commun. 8, 35 (1974).
[13] L. Grodzins, R. R. Borchers and G. B. Hageman, Nucl. Phys. 88, 474 (1966). L. Grodzins, B. Herskind, D. R. S. Somayajulu and B. Skaali, Phys. Rev. Lett. 30, 453 (1973).
[14] C. Baktash, J. X. Saladin, J. G. Alessi, J. J. O'Brien and F. D. Snyder, Bull. Am. Phys. Soc. 21, 976 (1976).
[15] R. L. Heath, *Ge(Li) and Si(Li) Spectrometry, Gamma-ray Spectrum Catalogue*, 3rd Edition, USAEC Report ANCR-1000-2 (1974).
[16] N. A. Voinova, D. M. Kaminker and Yu. V. Sergeenkov, Nucl. Phys. A235, 123 (1974).
[17] K. S. Krane and R. M. Steffen, Phys. Rev. C 3, 240 (1971).
[18] F. Todd Baker, Alan Scott, T. H. Kruse, R. M. Ronningen and J. H. Hamilton (unpublished).
[19] E. J. Bruton, J. A. Cameron, A. W. Gibb, D. B. Kenyon and L. Keszthelyi, Nucl. Phys. A152, 495 (1970).
[20] R. Béraud, I. Berkes, R. Chéry, R. Haroutunian, Michèle Lévy, G. Marguier, G. Marest and R. Rougny, Phys. Rev. C 1, 303 (1970).
[21] I. Berkes, R. Rougny, Michèle Meyer-Lévy, R. Chéry, J. Danière, G. Lhersonneau and A. Troncy, Phys. Rev. C 6, 1098 (1972).
[22] S. W. Yates, J. C. Cunnane, R. Hochel and P. J. Daly, Nucl. Phys. A222, 301 (1974).
[23] G. D. Benson, A. V. Ramayya, R. G. Albridge and G. D. O'Kelley, Nucl. Phys. A150, 311 (1970).
[24] K. Kumar, Phys. Lett. 29B, 25 (1969).