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Pure electric monopole transitions in an odd-mass nucleus

J. Schwarzenberg
School of Chemistry, Georgia Institute of Technology, Atlanta, Georgia 30332

J. L. Wood
School of Physics, Georgia Institute of Technology, Atlanta, Georgia 30332

E. F. Zganjar
Department of Physics and Astronomy, Louisiana State University, Baton Rouge, Louisiana 70803

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Six electric monopole ($E0$) transitions have been observed at low energy in ^{185}Pt: These transitions have no observed γ rays. The observation of pure $E0$ transitions and of such a large number of $E0$ transitions in an odd-mass nucleus is unprecedented. The phenomenon is consistent with the mixing of shape isomeric configurations.

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Electric monopole ($E0$) transitions [1] occasionally play a role in the decay of excited nuclear states. If the first excited state of a doubly even nucleus has spin parity $J^\pi=0^+$, it is the overwhelmingly dominant [2] decay mode to the 0^+ ground state and it takes place by either internal conversion (IC) or internal-pair (IP) formation. Sometimes higher-lying 0^+ states decay [1] by $E0$ transitions to the ground state in competition with electric quadrupole ($E2$) decay to a first excited 2^+ state. Very occasionally an excited state with nonzero spin will undergo a $\Delta J=0$, $\Delta\pi=$no transition to a lower-lying state by a transition with $E0$, $M1$, and/or $E2$ admixed multipolarities [3]. In odd-mass nuclei, $E0$ components in $\Delta J=0$, $\Delta\pi=$no transitions are extremely rare [4,5]. Further, because the spin of any state in an odd-mass nucleus is $\geq \frac{1}{2}$, γ-ray emission can always take place. We present evidence here for $\Delta J=0$, $\Delta\pi=$no transitions in ^{185}Pt for which we observe only internal conversion, i.e., we do not observe corresponding γ rays.

We have studied excited states in ^{185}Pt through the radioactive decay of mass-separated ^{185}Au (6.8 min, $J^\pi=\frac{5}{2}^-$) by using the UNISOR isotope separator operated on-line [6] to the 25-MV folded tandem accelerator at the Holifield Heavy-Ion Research Facility in Oak Ridge, Tennessee. The activity was produced by the (^{12}C,8n) reaction on a ^{181}Ta target using 140-MeV ^{12}C ions. Gamma-ray and conversion-electron spectrum multiscaling and γ-γ-t, γ-x-t, γ-ce-t, and ce-x-t coincidence measurements were conducted on line. Conversion-electron spectra were taken with a 200 mm$^2\times$3 mm cooled Si(Li) detector. All assignments of γ-ray and internally converted transitions were made on the basis of coincidence infor-

TABLE I. Energy, location, spin assignment, and lower limit on the conversion coefficients for the pure $E0$ transitions. For comparison, other transitions shown in Fig. 1 are included also. Errors for the α_K are shown, e.g., 0.071(14)≡0.071 ±0.014.

E_{trans} (keV)	$E_i \rightarrow E_f$	$J_i^\pi \rightarrow J_f^\pi$	$\alpha_K^{\text{expt a}}$	$\alpha_K^{\text{theory b}}$ $M1$	$E2$	Mult.
464.3	645.4 → 181.1	$\frac{1}{2}^- \rightarrow \frac{3}{2}^-$	0.071(14)	0.082	0.022	$M1(+E2)$
542.0	645.4 → 103.4	$\frac{1}{2}^- \rightarrow \frac{1}{2}^-$	> 2.0	0.055		$E0$
566.5	954.6 → 388.0	$\frac{1}{2}^- \rightarrow \frac{1}{2}^-$	> 2.8	0.049		$E0$
570.9	959.0 → 388.0	$\frac{3}{2}^- \rightarrow \frac{1}{2}^-$	0.035(10)	0.048	0.014	$M1+E2$
609.0	997.0 → 388.0	$(\frac{5}{2}^-) \rightarrow \frac{1}{2}^-$	0.010(4)	0.041	0.012	$E2$
537.2	1058.5 → 521.3	$\frac{3}{2}^- \rightarrow \frac{3}{2}^-$	> 2.5	0.056		$E0$
562.4	1083.7 → 521.3	$\rightarrow \frac{3}{2}^-$	0.043(10)	0.050	0.014	$M1(+E2)$
519.2	954.6 → 435.4	$\frac{1}{2}^- \rightarrow \frac{3}{2}^-$	0.075(30)	0.062	0.017	$M1$
523.5	959.0 → 435.4	$\frac{3}{2}^- \rightarrow \frac{3}{2}^-$	0.22(7)	0.060		$E0+\cdots$
537.5	972.9 → 435.4	$\frac{3}{2}^- \rightarrow \frac{3}{2}^-$	> 1.0	0.056		$E0$
597.0	1032.3 → 435.4	$\rightarrow \frac{3}{2}^-$	0.033(11)	0.043	0.013	$M1(+E2)$
623.1	1058.5 → 435.4	$\frac{3}{3}^- \rightarrow \frac{3}{2}^-$	> 1.4	0.038		$E0$
474.7[c]	1065.4 → 590.7	$(\frac{7}{2}^- \rightarrow \frac{7}{2}^-)$	> 2.0	0.078		$E0$

[a] Taken from Ref. [7].
[b] H. Roesel *et al.*, At. Data Nucl. Data Tables **21**, 91 (1978).
[c] Relevant spectra are not shown here.

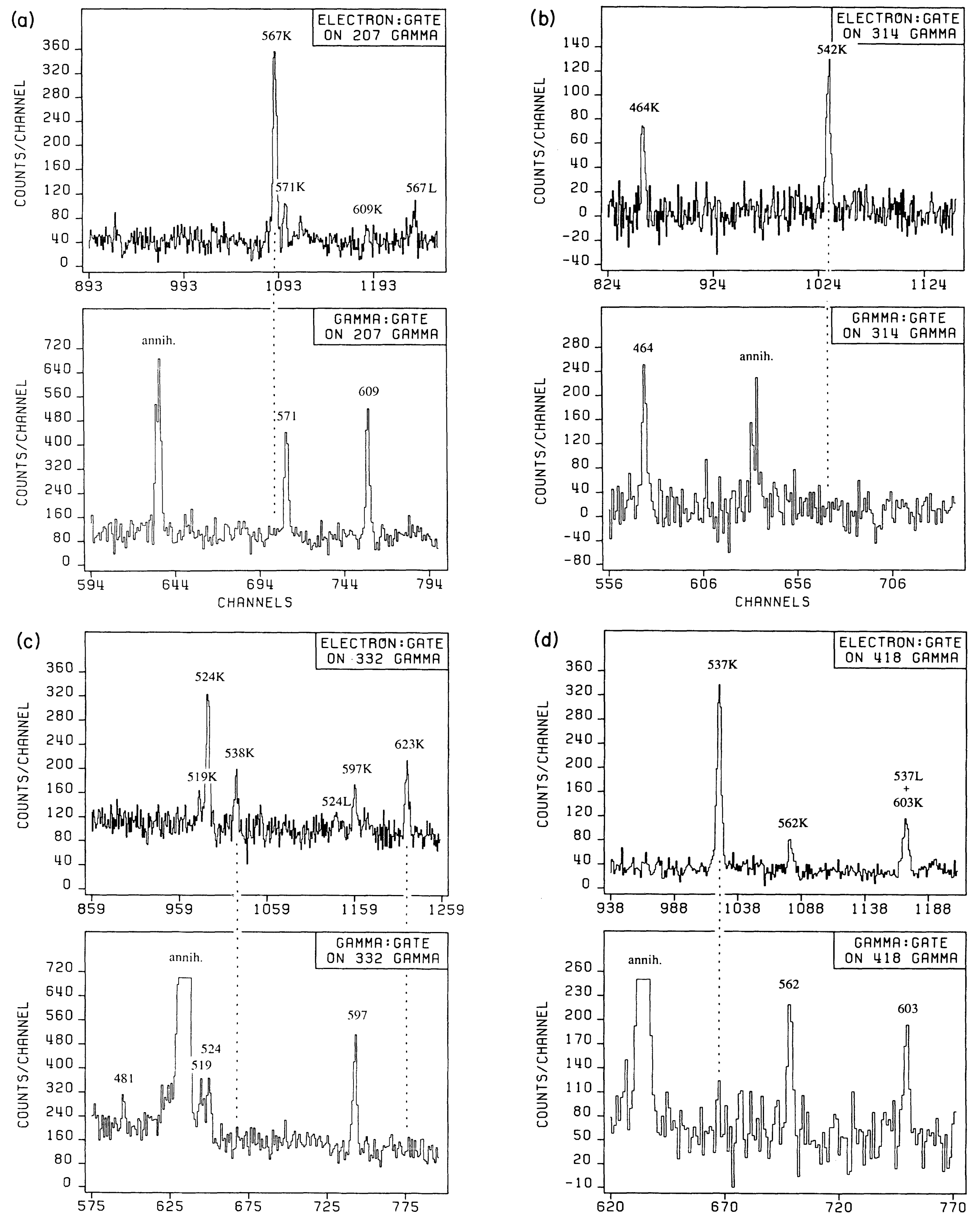

FIG. 1. (a)–(d) Gamma rays and conversion electrons in coincidence with gates set on the 207-, 314-, 332-, and 418-keV γ-ray lines. K-electron lines (which differ by a K binding energy of 78.4 keV from the γ rays) are aligned with the corresponding γ-ray lines. The positron annihilation lines at 511 keV in the γ-ray spectra are marked. The spectra have had events in coincidence with the Compton background under the gating lines subtracted. The vertical dashed lines are to guide the eye to where one would expect to see lines in the γ-ray spectra.

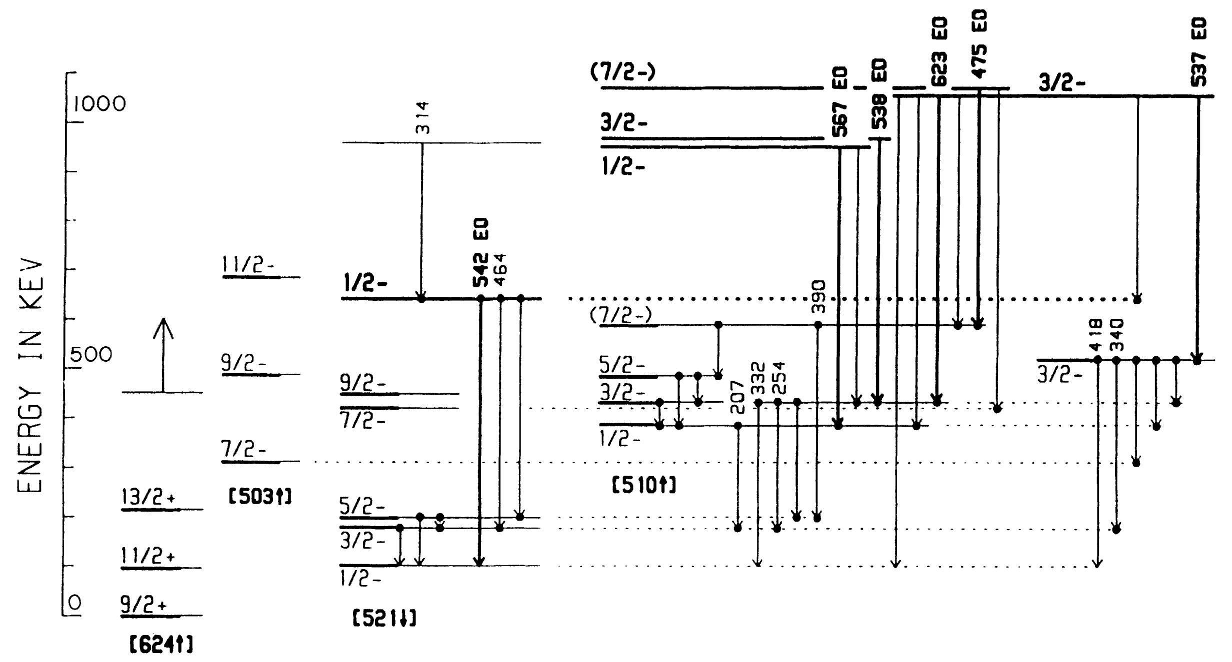

FIG. 2. Portions of the ^{185}Pt level scheme which are pertinent to this study. The levels from which pure $E0$ transitions originate are shown in bold print. The Nilsson band assignments are shown.

mation.

The evidence for the pure $E0$ transitions is given in Figs. 1(a)–1(d). These γ-γ and γ-e spectra provide a direct comparison of γ lines with K-conversion-electron lines. Besides the $E0$ transitions at 474.7, 537.2, 537.5, 542.0, 566.5, and 623.1 keV, other transitions are shown. The $E0$ transitions together with these other transitions are listed in Table I where we give K-internal-conversion coefficients, multipolarities, and location of the transitions in the ^{185}Pt level scheme. We note that the six pure $E0$ transitions listed in Table I have α_K values that are (at least) 20–60 times the theoretical $M1$ α_K values. We also note that there is a 523.5-keV transition with $E0$ admixture. This and other [7] transitions with $E0$ admixtures are not discussed here. Portions of the ^{185}Pt level scheme, relevant to this work, are shown in Fig. 2. This figure is based on a far more extensive scheme elucidated [7] from work done at UNISOR. It agrees, for the most part, with an earlier study [8] of the $^{185}\mathrm{Au} \rightarrow {}^{185}\mathrm{Pt}$ decay scheme except in a few critical details: Most notably, the $E0$ transitions reported here were not identified in the earlier study [8], except for the 542-keV transition which we assign as a transition between levels at 645.4 and 103.4 keV, in agreement with the earlier assignment [8]. However, we find the 542-keV line to be a doublet and assign all of the γ-ray intensity elsewhere, in serious disagreement with the earlier study [8]. We discuss this disagreement in [7,9] since it does not influence the conclusions that follow from the data presented here. We note that our study of the $^{185}\mathrm{Au} \rightarrow {}^{185}\mathrm{Pt}$ decay scheme differs from the earlier study [8] in that they did not assign conversion-electron intensity on the basis of coincidences. We show, in Fig. 3, the electron-gated γ spectra for gates set on the 537K (doublet) and 623K electron lines.

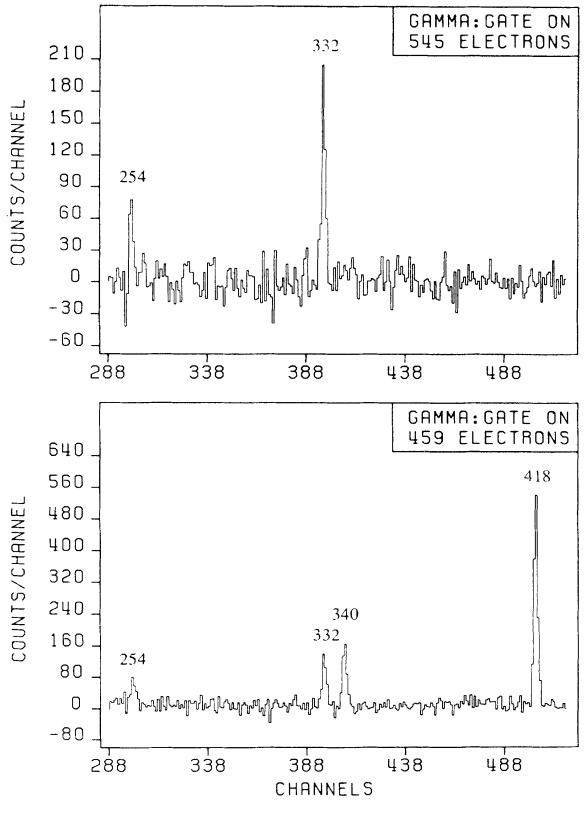

FIG. 3. Gamma rays in coincidence with gates set on the electron lines at 459 and 545 keV (537.2+537.5 and 623.1 K-electron lines). This shows that the 537.5- and 623.1-keV transitions are in coincidence with γ rays of 254.3 and 332.0 keV, and the 537.2-keV transition is in coincidence with γ rays of 340.3 and 417.9 keV; cf. Fig. 2.

Although the absence of observable γ-decay strength in the reported transitions is surprising, the occurrence of $E0$ strength in ^{185}Pt is not surprising. Electric monopole strength is expected [10] whenever configurations with different mean-square charge radii $\langle r^2 \rangle$ mix. There is extensive evidence that states with different deformation and therefore different $\langle r^2 \rangle$ occur in $^{175-187}$Pt: This is supported by energy-level systematics [11], $E2$ transition probabilities [11,12], and isotope shifts $(\delta\langle r^2 \rangle)$ [13]. We interpret the $E0$ transitions observed in this work as resulting from the mixing of low-lying strongly deformed configurations (cf. the Nilsson state assignments in Fig. 2) and higher-lying weakly deformed configurations. We do not undertake a discussion of the weakly deformed configurations here. However, we note that they can be expected to resemble low-lying states [14] in ^{187}Pt which has a weakly deformed ground state.

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[2] Two-photon decay is the only other observed process. For example, in the decay of the first excited state in ^{90}Zr ($E_x = 1761$ keV, $J^\pi = 0^+$) the relative decay probabilities are $P_{\mathrm{IC}}:P_{\mathrm{IP}}:P_{2\gamma} = 1.0:0.5:2\times 10^{-4}$. These data are taken from M. Nessin, T. H. Kruse, and K. E. Eklund, Phys. Rev. **125**, 639 (1962) and E. R. Mucciolo and O. Helene, Phys. Rev. C **40**, 2403 (1989).

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