JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN VOL. 34, SUPPLEMENT, 1973
PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON NUCLEAR MOMENTS AND NUCLEAR STRUCTURE, 1972

V.b. Investigation of Hexadecapole Moments with Coulomb Excitation*

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(Presented by J. S. Greenberg)

Recently acquired data on deformation parameters associated with the nuclear potential field distribution have posed some interesting questions regarding the multipole expansion of the deformed optical potential as a physical representation of the nuclear shape. A related question concerns the relationship between these potential shapes, derived from experiments with strong interaction probes, and the nuclear charge distribution. The complimentary information on the charge distribution can be obtained by well established techniques employing purely electromagnetic interaction mechanisms, such as Coulomb excitation. In the past Coulomb excitation has been one of the principle sources of information on static and transition E2 matrix elements. Under suitable experimental conditions the Coulomb excitation cross section is also sensitive to the electric hexadecapole interaction and therefore is a potential source of information on E4 matrix elements. We note, however, that the experimental Coulomb excitation probabilities yield the matrix elements directly, while the deformation parameters are extracted only through the assumption of a model for the nuclear shape.

Herein we report on hexadecapole transition moments for a number of deformed rare-earth nuclei. Precision measurements of $M(E2;0\rightarrow 2)$ were also extracted from the data. The experimental technique employed was inelastic scattering below the Coulomb barrier. Partly to check on the analysis procedures, cases were selected for which the E4 contribution to the excitation probabilities differed appreciably. Excitation with ^{4}He projectiles was employed for all the nuclei presented herein. Heavier projectiles, ^{16}O and ^{32}S, also were used for some of the studies to selectively emphasize, and thus separate, the E2 and E4 contributions to the excitation of rotational band members. The effective separation of the E2 and E4 excitation modes considerably reduces the model dependence of the analysis by avoiding assumptions on the spin dependence for the important E2 matrix elements within the rotational band. The selective sensitivity to E2 and E4 excitations derives from the characteristic behavior of the cross section with the excited state spin and projectile species; relative E4 excitations, for a state of a given spin, decrease with increasing projectile charge, but increase strongly with the spin of the state. Extensive studies of nuclear interference effects were performed, and the analysis was confined only to those projectile energies where nuclear interference was not detected.

The scattered ^{4}He ions were detected at $\sim 175°$ with Si detectors possessing ~ 15 keV resolution. The detector performance and the collimator system produced peak-to-valley ratios which allowed excitation probabilities to be extracted in most cases with an accuracy of $\sim 1\%$. A particle-γ ray coincidence arrangement was used for the heavier projectiles where

*Work supported by U.S.A.E.C. Contract AT(11–1)–3074

Table I.

	^{152}Sm	^{154}Sm	^{158}Gd	^{164}Dy	^{166}Er	^{168}Er	^{174}Yb
$M(E2)$(eb)	-1.835 ± 0.007	-2.066 ± 0.008	-2.225 ± 0.012	-2.368 ± 0.025	-2.399 ± 0.012	-2.458 ± 0.025	-2.433 ± 0.012
$M(E4)$(eb^2)	0.470 ± 0.070	0.653 ± 0.050	0.39 ± 0.09	0.25 ± 0.16	0.12 ± 0.18	0.12 ± 0.20	0.23 ± 0.17

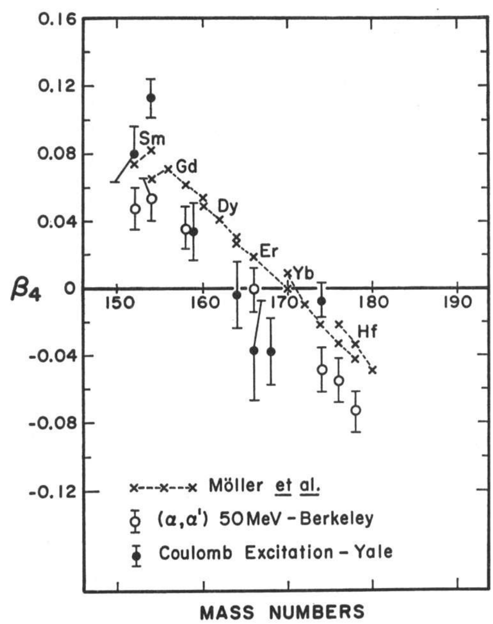

Fig. 1

the particle resolution was insufficient to resolve the close lying states in rotational nuclei. The γ ray detection experiments are normalized to the ^{4}He inelastic scattering measurements.

Preliminary results for $M(E2)$ and $M(E4)$ transition matrix elements are presented in Table I and Fig. 1, for some selected cases. Only part of the available data have so far been analyzed so that results quoting higher accuracy will be forthcoming. For ^{152}Sm and ^{154}Sm the results represent an analysis that fits all the available data simultaneously, including excitation with heavier projectiles and lifetime measurements.[1)] In the other cases, awaiting the analysis of heavy ion experiments, rotational model values have been assumed for the matrix elements in the ground state band based on our measured $M(E2;0\rightarrow 2)$, and the error for $M(E4)$ values quoted in Table I include the errors in the $M(E2;2\rightarrow 4)$ values derived from the $M(E2;0\rightarrow 2)$ measurements. For comparison Fig. 1 does not reflect these additional uncertainties in the cases where rotational model matrix elements were assumed. The effects of high spin states (up to 8^+) in the ground state band and higher lying bands were considered and included in the analysis.

In Fig. 2 the β_4 values were derived from the measured $M(E2)$ and $M(E4)$ values, the rotational model, and a Fermi charge distribution with constants deduced from electron

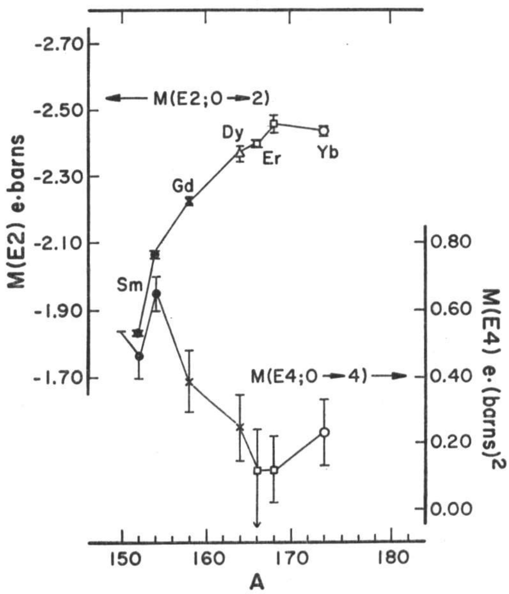

Fig. 2

scattering.[2] A uniform charge distribution with $R=1.2A^{1/3}$ fm yields larger β_4 values. Except for ^{152}Sm and ^{154}Sm the β_4 values deduced from the measurements herein agree both in trend and magnitude with the results from (α,α') measurements well above the Coulomb barrier.[3] We point out the discrepancy with the nuclear potential scattering in the cases of ^{152}Sm and ^{154}Sm for which we obtain β_4 values of 0.080 ± 0.016 and 0.113 ± 0.011 respectively compared to the corresponding values from ref. 3 of 0.048 and 0.054 based on $R=1.2A^{1/3}$ fm. A similar discrepancy for these two nuclei has been noted in experiments using different experiments using different experimental techniques.[1,2]

References

1) F. S. Stephens *et al.*: Phys. Rev. Letters **27** (1971) 1151.
2) W. Bertozzi *et al.*: Phys. Rev. Letters **28** (1972) 1171.
3) D. L. Hendrie *et al.*: Phys. Letters **26B** (1968) 127.

Discussion

H. H. STROKE (New York Univ.): Have you compared your results to the static hexadecapole moments measured by Penselin's group at Bonn for Ho, Dy and Hf?

GREENBERG: No, we have not.

STROKE: It would appear to me that this would be fruitful in the interpretation of the data.