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QUADRUPOLE MOMENT OF THE FIRST EXCITED STATE IN $^{36}\text{Ar}^\dagger$

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November 1970

The static quadrupole moment of the first excited state in ^{36}Ar has been measured by the reorientation effect in projectile Coulomb excitation. The results are $Q(^{36}\text{Ar}, 2^+) = (+0.11 \pm 0.06)b$ and $B(E2; 0^+ \rightarrow 2^+) = (0.032 \pm 0.005)e^2b^2$.

- - -

A series of experiments [1,2] has been carried out at the Berkeley HILAC to measure quadrupole moments of the first excited states of even-even nuclei in the 2s-1d shell. The method used was to measure the reorientation effect [3] in projectile Coulomb excitation; the sensitivity to the effect is a factor of five or more greater than in the usual target reorientation method, so that the uncertainties in the results are correspondingly reduced. The nuclei whose first-excited-state quadrupole moments were previously measured using this method [1,2] are $^{20,22}\text{Ne}$, ^{28}Si , ^{32}S , and ^{40}Ar . Recently a number of Hartree-Fock calculations have been published for the 4n nuclei in the 2s-1d shell [4]. The experimental results on the shapes of ^{20}Ne , ^{24}Mg (prolate shape; $Q_0 > 0$) and ^{28}Si (oblate shape; $Q_0 < 0$) are reasonably well reproduced by the calculations, but the

[†]Work performed under the auspices of the U. S. Atomic Energy Commission.

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result on $^{32}\text{S}(Q_0 > 0)$ is not. The change of sign of Q_0 between ^{28}Si and ^{32}S appears to indicate a difficulty in predicting deformations of nuclei in this region of the 2s-1d shell. We then became interested in ^{36}Ar , and so measured the static quadrupole moment of the first 2^+ state of this nucleus by the same method as in the previous experiments. The details of the method are described in ref. 1.

The ^{36}Ar beam was accelerated to ~ 150 MeV by the HILAC and then struck a ^{206}Pb target (~ 1.5 mg/cm²). Gamma-ray spectra in coincidence with a ring counter for particles scattered at 160° and with a circular particle counter at 90° have been taken simultaneously. The ratio of the γ -ray yields of the projectile, $^{36}\text{Ar}(2^+, 1.970$ MeV), to those of the target, $^{206}\text{Pb}(2^+, 0.803$ MeV), at each angle (R^{90} , R^{160}) were obtained, together with the double ratio $R = R^{160}/R^{90}$, as shown in fig. 1. The solid lines in the figure are the best fits obtained by least-square fitting using the deBoer-Winther Coulomb excitation program. The two parameters determined in the fitting were: 1) the intrinsic quadrupole moment Q_0 from the $B(E2, 0^+ \rightarrow 2^+)$, and 2) the ratio of the static quadrupole moment Q of the 2^+ state to the rotational moment Q_r deduced from Q_0 [7]. For the target excitation the $B(E2, 0^+ \rightarrow 2^+)$ in ^{206}Pb is known [5], but the static moment of the 2^+ state is not, so that we assumed $Q(^{206}\text{Pb}, 2^+) = 0.0 \pm 0.5 |Q_r(^{206}\text{Pb}, 2^+)|$. This assumption introduces some uncertainty into the result; however, as discussed in the previous paper [1], this method of comparing with target excitation measured simultaneously has a number of advantages.

Corrections have been made for: 1) the attenuation of the γ -ray angular distribution; 2) the finite solid angles of both particle and γ detectors; and

3) the change of detection efficiency of γ -rays due to the recoil motion. The lack of data on the transition probabilities between the ground or first excited state and the other low-lying states in ^{36}Ar made the correction for effects due to those states ambiguous. These effects were estimated using deformation parameters determined from inelastic scattering experiments [6], and rather conservative errors were included for these corrections. The static quadrupole moment obtained is

$$Q(^{36}\text{Ar}, 2^+) = (+0.11 \pm 0.06)b$$

with the positive value of the moment indicating an oblate shape for the nucleus.

In fig. 2 we have added the new point to a model-dependent plot of Q_0 in 2s-1d shell nuclei which was published previously [2]. Three noticeable features in this plot are the remarkably similar magnitudes of $|Q_0|$ obtained from the values of $B(E2, 0^+ \rightarrow 2^+)$ measured for the seven doubly-even nuclei, the rather large positive static moment Q_0 of ^{32}S , and the fact that the static moments are $\sim 30\%$ larger than the rotational value for the light nuclei, $^{20,22}\text{Ne}$, ^{24}Mg . The last two features were rather unexpected. It now appears, however, that these features may be examples of a general trend toward more positive values for the moments.

1) It could be due to a systematic experimental error. This seems somewhat unlikely because three different types of experiments [1,8,9] in the Ne - Mg region showed the same size deviations from the rotational values. 2) There may be some unknown effect(s) not included in the analysis of the Coulomb excitation process. Such effects are much more likely than (1) to affect all

three types of measurement in a similar way. It is hard to exclude this possibility entirely. 3) This may be a real nuclear effect which results from some collective (or at least systematic) property of these nuclei that is not yet completely recognized.

We are indebted to the HILAC crew for their help during the experiments. We wish to thank Drs. J. R. Leigh, K. H. Maier, and J. L. Québert for their interest and discussions. One of us (K.N.) is grateful to the Lawrence Radiation Laboratory for the excellent working conditions.

References

1. K. Nakai, F. S. Stephens, and R. M. Diamond, Nucl. Phys. A150 (1970) 114.
2. K. Nakai, J. L. Québert, F. S. Stephens, and R. M. Diamond, Phys. Rev. Letters 24 (1970) 903.
3. J. deBoer and J. Eichler, in Advances in Nuclear Physics, ed. by M. Baranger and E. Vogt, Plenum Press, New York, (1968) Vol. 1.
4. G. Ripka, in Advances in Nuclear Physics, ed. by M. Baranger and E. Vogt, Plenum Press, New York, (1968) Vol. 1; J. Bar-Touv, A. Goswami, A. L. Goodman, and G. L. Struble, Phys. Rev. 178 (1970) 1670; S. J. Kriger, Phys. Rev. C 1 (1970) 76, and references therein.
5. J. L. Québert, K. Nakai, R. M. Diamond, and F. S. Stephens, Nucl. Phys. A150 (1970) 68.
6. M. C. Mermaz, C. A. Whitten, Jr., and D. A. Bromley, Phys. Rev. 187 (1970) 1466; R. R. Johnson and R. J. Griffiths, Nucl. Phys. A117 (1968) 273.
7. Q_0 is related to Q or to the $B(E2, 0^+ \rightarrow 2^+)$ value in a model-dependent way using the formulae;

$$Q = \frac{3k^2 - I(I+1)}{(I+1)(2I+3)} Q_0 \quad \text{or} \quad B(E2, 0^+ \rightarrow 2^+) = \frac{5e^2}{16\pi} Q_0^2$$

$|Q_r|$ is given by

$$|Q_r| = \frac{2}{7} \sqrt{\frac{16\pi B(E2, 0^+ \rightarrow 2^+)}{5e^2}}$$

8. O. Häusser, B. W. Hooton, D. Pelte, T. K. Alexander, and H. C. Evans, Phys. Rev. Letters 22 (1969) 359 and Phys. Rev. Letters 23 (1969) 320.
9. D. Schwalm and B. Povh, Phys. Letters 29B (1969) 103; A. Bamberger, P. G. Bizzetti, and B. Povh, Phys. Rev. Letters 21 (1968) 1599.

Table I. Summary of the least-square fitting.

²⁰⁶ Pb Target Values		Result for ³⁶ Ar	
B(E2, 0 ⁺ → 2 ⁺)	Q(2 ⁺)	B(E2, 0 ⁺ → 2 ⁺)	Q(2 ⁺)
e ² × 10 ⁻⁵⁰ cm ⁴	b	e ² × 10 ⁻⁵⁰ cm ⁴	b
9.1±0.6 ^a	+0.5 Q _r	3.2±0.5	+0.091±0.052
	0.0	3.2±0.5	+0.107±0.052
	-0.5 Q _r	3.2±0.5	+0.124±0.052
9.1±0.6 ^a	0.0±0.5 Q _r ^b	3.2±0.5 [*]	+0.11 ±0.06 [*]

^aReference 5.

^bAssumption; | Q_r | is the value calculated from the B(E2) using the rigid-rotor model.

* Possible systematic errors of (±5%) have been included.

Figure Captions

Fig. 1. Result of the experiment and analysis. The solid lines are the best fits and the dashed lines show the curves for $Q = 0$ or $\pm |Q_r|$. The arrow indicates the safe energy, E_s , defined in ref. 3.

Fig. 2. Intrinsic quadrupole moments, Q_0 [7], in the 2s-1d shell nuclei. The present result on ^{36}Ar has been added to the figure from ref. 2. The circles indicate the Q_0 of the first-excited 2^+ states deduced from measured static quadrupole moments by: the present method (double circles), the method of the Chalk River group [8] (closed circles) and that of the group at Heidelberg [9] (open circles). The squares indicate the values calculated from measured $B(E2, 0^+ \rightarrow 2^+)$ values. The intrinsic moments of odd-A nuclei deduced from the spectroscopic quadrupole moments (assuming $K = I$ except for $^{19}\text{F}^*$ ($K = 1/2, I = 5/2$)) are shown by the diamonds.

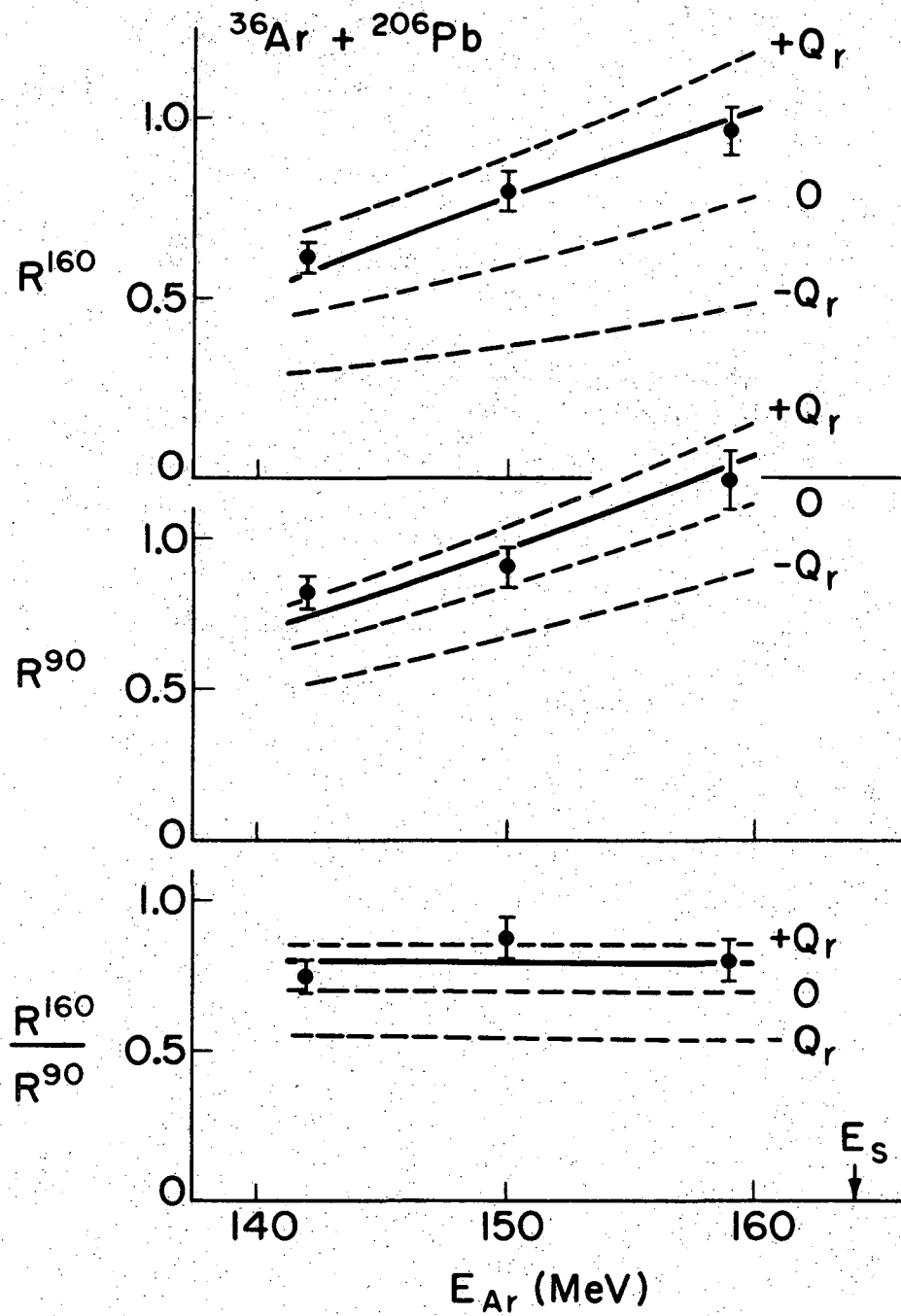
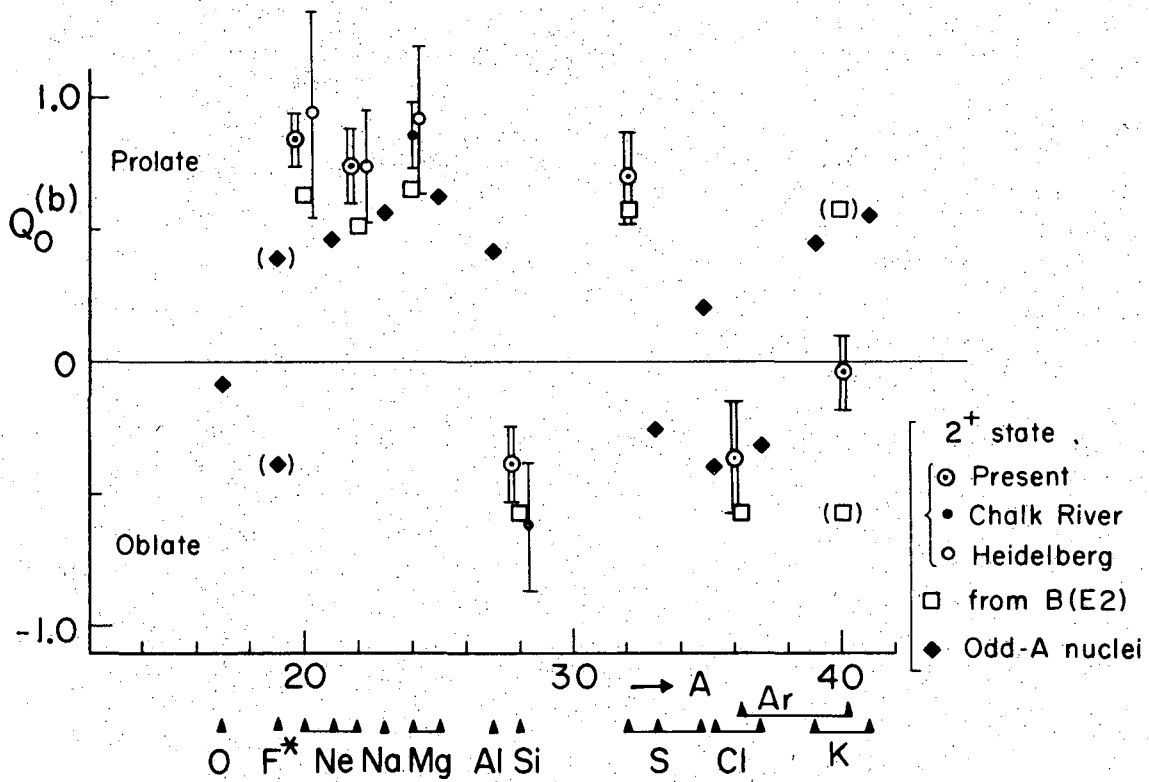


Fig. 1

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XBL 701-2137

Fig. 2

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