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II.g. Experimental Foundations of the Reorientation Effect*

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The unambiguous determination of static quadrupole moments by Coulomb excitation depends sensitively on the experimental conditions in the individual experiments. In order to realize the full potential of the reorientation effect as a method of determining static quadrupole moments, a number of questions need to be answered by experiment: (1) What experimental conditions are required so that the effect of the nuclear force is entirely negligible? (2) How can the reorientation effect be "calibrated" or cross-checked with other methods of measuring nuclear quadrupole moments? (3) What experimental conditions are required to reduce the contributions from higher states to negligible proportions?

In order to answer the first question a search was conducted for a nucleus and projectile where a substantial reorientation effect occurs, and where multiple Coulomb excitation effects are negligible. Then it would be possible to study the energy dependence of the reorientation effect. The energy dependence for a particular projectile and target would give detailed information about the "safe" bombarding energy. ^{16}O ions incident on ^{56}Fe nuclei were selected for this study. The influence of nuclear interference on the reorientation effect was observed before it could be detected on the elastic cross section, and exhibited an angular dependence similar to that expected for the reorientation effect. It was found that an appropriate separation of projectile and target nuclei was given by $2a = R_0(A_1^{1/3}+A_2^{1/3})+\Delta$, where R_0 and Δ are given in Table I.

In order to avoid erroneous results the conservative values $R_0=1.6$ fm and $\Delta>3.5$ fm should be used. A number of published measurements violate this criteria.

In order to calibrate the reorientation effect with traditional measurements the static quadrupole moment of the $3/2^-$ ground state of ^{53}Cr has been determined. Thin targets of enriched ^{53}Cr were bombarded by ^{32}S projectiles. The relative excitation probability of the 0.564 MeV spin $1/2^-$ first excited state was measured as a function of projectile scattering

Table I. Coulomb excitation of ^{56}Fe.

	R_0(F)	Δ	E_{max} (MeV) ^{16}O	^{32}S
deBoer-Eichler[1]	1.25	3.0	35.1	80.2
Cline *et al.*[2]	1.6	3.0	29.2	66.3
This work[3]	1.6	3.5	28.1	64.0

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angle with our particle-γ-ray coincidence technique. From this data the static quadrupole moment of the $3/2^-$ ground state was determined to be $Q=+0.04\pm0.06$ b. This result is in agreement with the value $|Q|=0.026$ b determined from NMR data. Because of the very small value of the quadrupole coupling constant uncertainties in the calculated electric field gradient do not obscure the extraction of a relatively certain value of the quadrupole moment of the ground state of ^{53}Cr in the NMR measurement.[4] The quadrupole moment determined in the present reorientation effect experiment is in agreement with the value of the quadrupole moment found by the NMR method. This agreement indicates that the reorientation effect is the dominant higher order process which can contribute to the excitation probability of the first excited state of ^{53}Cr.

To further cross-check the reorientation effect, we have made a precise determination of the quadrupole moment of the first 2^+ state in ^{170}Er. This nucleus was selected because it is highly deformed and has a rotational energy spectrum. Thus, a comparison between a "known" rotational quadrupole moment and the result of a reorientation experiment is feasible. A ^{81}Br projectile was used to maximize the magnitude of the reorientation effect. An additional advantage is gained with this heavy, low energy ($\sim$0.7 MeV/nucleon) beam because there are no appreciable higher state corrections. We find $Q=1.95\pm0.26$ b for the 79 keV 2^+ state in ^{170}Er, in excellent agreement with the rotational value $Q_R=2.12\pm0.04$ b. This powerful technique using slow, very heavy projectiles can be used in many regions of the periodic table and will allow us to realize the full potential of the reorientation effect.

References

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