Inelastic electron scattering form factors for the excitation of $6^+$ states in the N=28 nuclei

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Abstract. By using the correlated operators generated within the framework of the first-order perturbation theory, we obtain simultaneously an enhancement of the C6 form factor for $^{50}$Ti around the first peak, compared to the single-particle-model prediction, and a reduction of the C6 form factor for $^{52}$Cr in the same momentum-transfer range, both cases being consistent with the experiments. It is the two-body form of the transition operators that plays a crucial role in elucidating this long-standing puzzle.

1. Introduction
Cross sections were measured for inelastic electron scattering from $^{50}$Ti by the Amsterdam group [1], and both charge and magnetic form factors have been extracted over a wide momentum-transfer range. The charge form-factor data for the excitation of the yrast $J^\pi = 2^+$, $4^+$ and $6^+$ states show that the polarization charges deduced by fitting the data with the $(1f_7/2)^2$ model are decreasing as a function of the multipole order but are still positive for the $J^\pi = 6^+$ state. This result confounded the experimentalists, because various higher-order mechanisms had been invoked theoretically [2] to explain the negative polarization charge which was required to reproduce the $0^+ \rightarrow 6^+$ transitions observed in the neighbouring nuclei $^{50,52}$Cr. Moreover, E6 γ transition strength deduced from the isomeric $19/2^-$ state to the $7/2^-$ ground state in $^{53}$Fe demonstrates [3] that the polarization charge required to fit the data should be negative and extremely large: $-0.5e$, which has even kept off every theoretically proposed mechanism.

The purpose of the present paper is to make extensive calculations for C6 form factors in this isotones to clarify the confusing question.

2. Theory
The theoretical framework is the same as described in the previous calculation [4]: The $f_{7/2}^{2n}$ configuration is assumed for the sake of simplicity. The correlated transition operator $\tilde{f}^{(\kappa \lambda)}$ is defined by the first-order perturbation in the mixing interaction $V$:

$$\tilde{f}^{(\kappa \lambda)} = f^{(\kappa \lambda)} + f^{(\kappa \lambda)} \frac{Q}{E - H_0} V + V \frac{Q}{E - H_0} f^{(\kappa \lambda)}. \quad (1)$$

The harmonic oscillator wave functions with the oscillator constant $\nu = (0.96 \times A^{-1/3}) \times 0.8$ are assumed, and the excitations up to the $22\hbar \omega$ are taken into account in order to make secure the convergence.

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Figure 1. Calculated and experimental $|F|^2$ for the C6 transitions in $^{50}$Ti and $^{52}$Cr. The dotted-dashed, the double-dotted-dashed, the dotted and the dashed curves show the one-body, the two-body, the perturbed (one-body + two-body) and unperturbed contributions. The total form factors (unperturbed + perturbed) are given by the solid lines. The experimental data denoted by circle are taken from [1], triangle from [5] and square from [6].

3. Results and Discussion
We assume for the mixing interaction $V$ the Wigner-Yukawa(WY), M3Y, Schiffer-True, $\delta$-function, Serber-Yukawa and Rosenfeld-Yukawa interactions, which are characterized by their triplet-odd component $V(\text{TO})$ being negative, zero and positive. Calculated squared form factors $|F|^2$ with the WY interaction are compared in Figure 1 with the experimental ones.

The one-body contributions, having a bell shape and weak mass dependence, are added destructively to the unperturbed ones in the former group, $V(\text{TO}) < 0$, whereas constructively in the later two groups $V(\text{TO}) \geq 0$, throughout the shell. Therefore, an enhancement in $^{50}$Ti and a reduction in $^{52}$Cr, as observed in experiment, cannot be obtained simultaneously, as far as only the core-polarization mechanism is considered.

The two-body contributions, having a different shape and relatively strong mass dependence, are added in phase in the high-$q$ region in both these two groups. In the $V(\text{TO}) = 0$ group, both these contributions being almost the same size, we always get a considerable enhancement in the form factors, which overestimate the experiment. In the $V(\text{TO}) < 0$ group, on the other hand, the two-body contributions, which are significantly larger than the one-body contributions in a certain $q$-range and also mass dependent, can produce different aspects in each form factor: In $^{50}$Ti, the form factor in the peak region is enhanced significantly, while in $^{52}$Cr the form factor in the lower-$q$ region is reduced and that in the higher-$q$ region is increased considerably, both cases yielding the theoretical form factors in good agreement with experiment.

It is therefore concluded that two-body form of the transition operators is indispensable in interpreting the C6 form factors of the N=28 nuclei.

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