

TRANSITIONS FROM THE TWO-PHONON STATES TO THE ONE-PHONON
STATE IN EVEN Cd ISOTOPES

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It has been considered for a long time that transitions from the two-phonon states to the one-phonon state in even Cd isotopes conserve their collective character, in spite of the large anharmonicities revealed by measurements of the quadrupole moment. Recent experiments, however, have shown that the intensities of these transitions strongly violate the harmonic vibrational rule

$$R(I_2^+ \text{ ph} \rightarrow 2_1^+) = 2, \quad I = 0, 2, 4,$$

and that this deviation from harmonicity is of the same order as for the quadrupole moment [1-8].

Suspecting that this behaviour might originate from an interference of collective and individual modes of excitation [9-11], we performed a set of calculations by coupling two proton holes to a harmonic vibrator created by neutrons. The parameters (single particle level positions ϵ_j , the pairing strength G and the particle-vibrator coupling constant a) were systematically varied in order to investigate the stability of results and possibilities for describing several adjacent even Cd nuclei.

Fig. 1 shows a comparison of experimental data and theoretical results obtained by diagonalization for the $2_2^+ \rightarrow 2_1^+$ transition, for which experimental data are most abundant [4-7]. The ratio $R(2_2^+ \rightarrow 2_1^+)$ is plotted against the energy ratio E_4^+/E_2^+ , which, in calculation, increases with growing coupling constant a .

The theoretical curves show the following characteristics. For $a=C$, the ratio R is either 0 or 2, depending

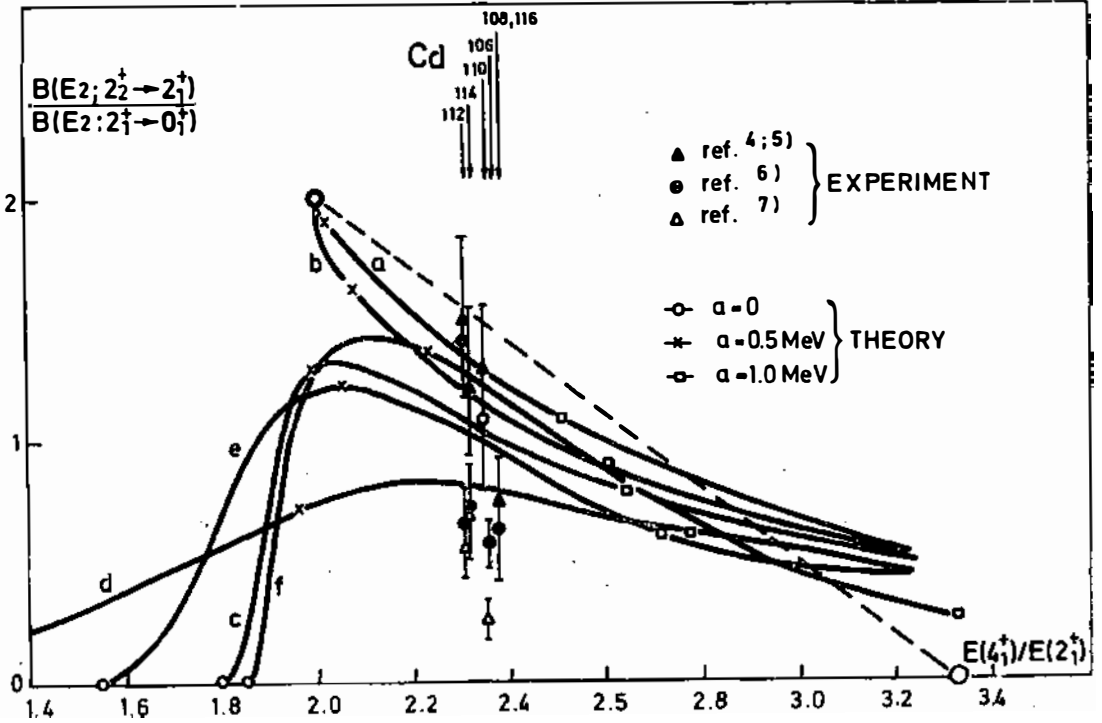


Fig.1. Calculated and experimental values of the ratio $R(2_2^+ \rightarrow 2_1^+)$ as a function of the energy ratio E_{4^+}/E_{2^+} . The calculated results refer to the following choice of the parameters:

- a) $g_{9/2}^{-1}$, $G = 0.60$ MeV, $\hbar\omega = 1$ MeV
- b) $g_{9/2}^{-1}$, $G = 0.44$ MeV, $\hbar\omega = 1$ MeV
- c) $g_{9/2}^{-1}$, $G = 0.36$ MeV, $\hbar\omega = 1$ MeV
- d) $g_{9/2}^{-1}$, $G = 0.20$ MeV, $\hbar\omega = 1$ MeV
- e) $g_{9/2}^{-1}$, $p_{1/2}^{-1}$, $p_{3/2}^{-1}$; $\epsilon(p_{1/2}^{-1}) - \epsilon(g_{9/2}^{-1}) = 0.36$ MeV,
 $\epsilon(p_{3/2}^{-1}) - \epsilon(g_{9/2}^{-1}) = 0.65$ MeV, $G = 0.2$ MeV, $\hbar\omega = 0.86$ MeV
- f) $g_{9/2}^{-1}$, $p_{1/2}^{-1}$, $p_{3/2}^{-1}$, $f_{5/2}^{-1}$; $\epsilon(p_{1/2}^{-1}) - \epsilon(g_{9/2}^{-1}) = 0.36$ MeV,
 $\epsilon(p_{3/2}^{-1}) - \epsilon(g_{9/2}^{-1}) = 0.65$ MeV, $\epsilon(f_{5/2}^{-1}) - \epsilon(g_{9/2}^{-1}) = 1.2$ MeV, $G = 0.2$ MeV, $\hbar\omega = 0.86$ MeV.

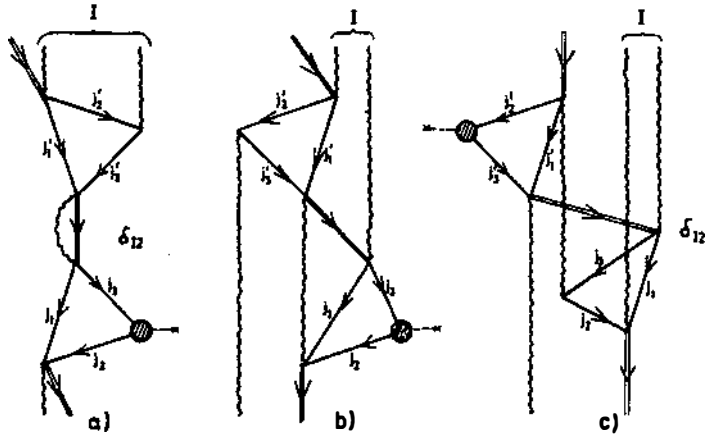


Fig. 2. Possible types of triangular contributions to the $I^+ \rightarrow 2_1^+$ transition matrix elements (for $I = 2^+, 4^+$). The double line denotes a $J=0$ hole pair.

on whether the 2_2^+ state was originally a two-phonon or a two-hole state. The pure states, however, mix strongly when the particle-vibration interaction is switched on, leading to the appreciably quenched transition rates in the region of intermediate coupling.

Comparison with experimental data shows that the present model gives a satisfactory qualitative description of the $2_2^+ \rightarrow 2_1^+$ transition. Theoretical results depend moderately on the relative magnitude of the harmonic phonon energy $\hbar\omega$ and the ground-state pairing shift Δ . In the region of the correct energy spacing, the calculated values lie within the overall experimental error, although they are somewhat too high in comparison with recent measurements [7].

Similar calculations were performed also for $0_2^+ \rightarrow 2_1^+$ and $4_1^+ \rightarrow 2_1^+$ transitions. The common feature of the

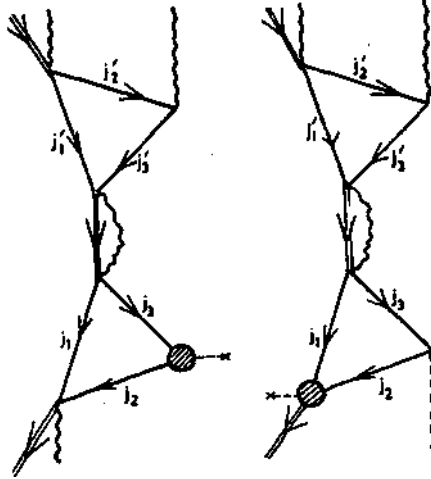


Fig.3. Leading triangular contributions of the particle type to the $2_2^+ \rightarrow 2_1^+$ matrix element.

results obtained is a decrease of the $B(E2)$ ratio with increasing coupling strength. The deviation from the harmonic value is much smaller for the $4_1^+ \rightarrow 2_1^+$ and somewhat stronger for the $0_2^+ \rightarrow 2_1^+$ transition, in agreement with experiment.

The perturbative calculation was performed to extract elementary processes responsible for quenching of the $2\text{ ph} \rightarrow 1\text{ ph}$ transitions. It is found that both first and second orders leave the harmonic ratio (1) conserved. Third and fourth orders allow only for quadrangular graphs. They exhibit a large degree of incoherence between particle and vibrational parts, as well as between different diagrams of the same type. Therefore, their contribution is relatively small.

Largest contributions come from diagrams of the triangular type, which occur for the first time in fifth and sixth order. Typical examples of possible

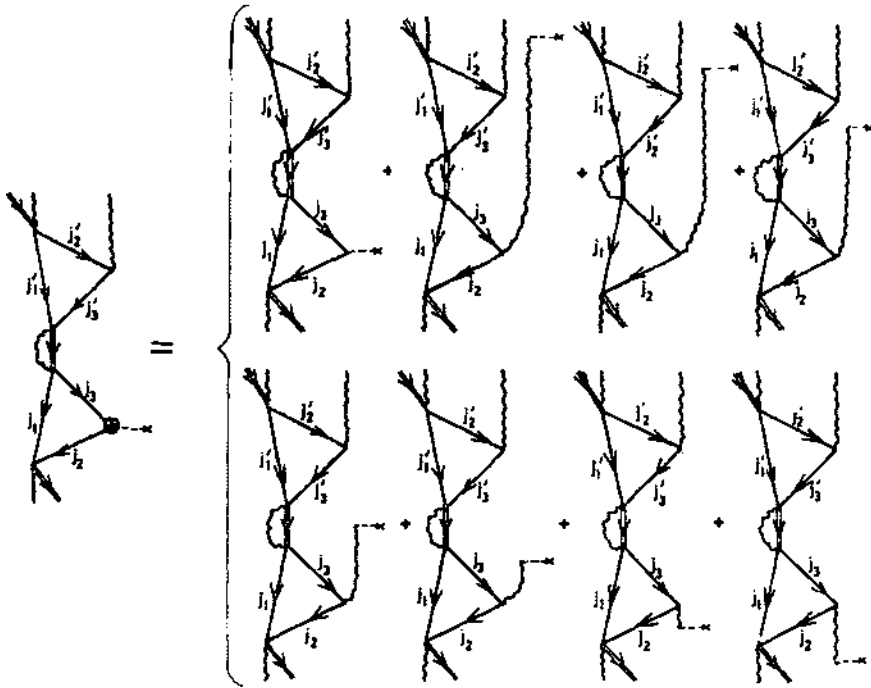


Fig.4. Vibrational processes responsible for the induced effective charge in fig. 3.

fifth order diagrams are shown in fig. 2. The largest correction is due to diagrams of type a, and they occur only for $I = .2$. That is the reason why the $2_2^+ \rightarrow 2_1^+$ transition is much more quenched than the $4_1^+ \rightarrow 2_1^+$ transition.

The two important diagrams of type a are shown in fig. 3. They have the character of particle transitions. The shaded circles represent the effective charge which is several times enhanced compared with the charge of the proton. The origin of this enhancement lies in the vibrational processes shown in fig. 4. This large polarization effect and the small energy denominator of the type $(\Delta - \hbar\omega)^{-2} \cdot (\Delta - 2\hbar\omega)^{-2}$

together build a large negative term which has to be added to the zeroth-order matrix element and which explains the quenched $2_2^+ \rightarrow 2_1^+$ transition probability.

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