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Nonadiabaticity of Beta-Vibrations in the Davydov Model (*).

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The interaction of beta- and gamma-vibrations with nuclear rotations has been investigated by DAVYDOV (1) as a natural extension of the original model proposed by DAVYDOV and FILIPPOV (2). DAVYDOV (1) has obtained an expression for the energy of the total collective excitations of an asymmetric nucleus and has studied the conditions under which the beta-vibrations would be separated from other collective excitations of the nucleus. When the nonadiabaticity parameter μ is smaller than $\frac{1}{3}$ and the nonaxiality parameter γ_0 is greater than 10° the collective excitation-energy can be explicitly written as

$$(1)\qquad \frac{E(\lambda k\,{}^nI)}{\hbar\omega_\beta} = (k+0.5)+\alpha(\lambda+0.5)+\frac{\mu^2}{2}\left[\frac{\varepsilon({}^nI)}{2}-C+6\alpha(k+0.5)(\lambda+0.5)-\right.$$
$$\left.-4\alpha^2(\lambda+0.5)^2\right]+\frac{\mu^4}{2}\left[\frac{3}{2}(k+0.5)\varepsilon({}^nI)-3(k+0.5)C-2\alpha(\lambda+0.5)\,\varepsilon({}^nI)+\right.$$
$$\left.+4\alpha(\lambda+0.5)C-57\alpha^2(k+0.5)(\lambda+0.5)^2\right]-\frac{\mu^6}{2}\left\{\left[\frac{\varepsilon({}^nI)}{2}\right]^2+C^2-\varepsilon({}^nI)C+\right.$$
$$\left.+\frac{57}{2}(k+0.5)(\lambda+0.5)\alpha\varepsilon({}^nI)-57\alpha(k+0.5)(\lambda+0.5)C\right\}-$$
$$-\frac{57}{8}\mu^8\left\{(k+0.5)\left[\frac{\varepsilon({}^nI)}{2}\right]^2+(k+0.5)C^2-(k+0.5)\,\varepsilon({}^nI)C\right\},$$

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(1) A. S. DAVYDOV: *Nucl. Phys.*, **24**, 682 (1961).

(2) A. S. DAVIDOV and G. F. FILIPPOV: *Nucl. Phys.*, **8**, 237 (1958).

where $C = 2.25[1+\sin^{-2}(3\gamma_0)]-2$, $\varepsilon(^nI)$ are the energies of the asymmetric-rotor model in units of $\hbar^2/4B\beta^2$, k and λ are quantum numbers related to beta ($k=1$, $\lambda=0$) and gamma ($k=0$, $\lambda=1$) vibrations, $\alpha=\hbar\omega_\gamma/\hbar\omega_\beta$ is the ratio between the second-excited 0^+ state ($k=0$, $\lambda=1$) and the first-excited 0^+ state ($k=1$, $\lambda=0$). This ratio is given as a certain function of the parameters μ and γ_0 through eq. (1). It is related to the parameter D used by DAVYDOV (1) by the expression $\alpha=\mu^2\sqrt{D}$.

As is well known the vibrational nuclei can be considered very soft so that their μ-value is greater than $\frac{1}{3}$; in the transuranic nuclides the parameter γ_0 is smaller than 10°. Therefore it is not possible to apply the restricted formula to these nuclei. On the other hand, the conditions for the validity of this formula might *a priori* be fulfilled by the rare-earth nuclei.

Consequently, the aim of this work was to investigate the applicability of eq. (1) to describe the excited states in even-even rare-earth nuclei. From the physical point of view it means, according to DAVYDOV, to search for the feasibility of an adiabatic treatment of beta-vibrations in this region.

The first step was to look for self-consistent values of the parameters γ_0 and μ utilizing suitable experimental data, *i.e.* the energies of several pairs of excited states. As zeroth-order approximation, the values of those parameters obtained from the fitting of experimental data with the theoretical prediction of the Davydov-Chaban (3) model were used. When this was not possible, pairs of values satisfying the conditions imposed were tried.

A somewhat surprising result was obtained indicating that for all the considered nuclei, at a certain state of the iterative process, the parameters got out of the range of validity of eq. (1). Consequently, convergence was never reached.

These results give allowance to conclude that the nuclei under study ($60\leqslant Z\leqslant 76$, $90\leqslant N\leqslant 114$) exhibit an energy spectrum which cannot be consistently fitted with the restricted formula given by DAVYDOV (1). This fact should also indicate that an adiabatic treatment of beta-vibrations within the framework of the Davydov model cannot be made, at least in principle, for any nucleus.

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(3) A. S. DAVYDOV and A. A. CHABAN: *Nucl. Phys.*, **20**, 499 (1960).