De-excitation of 2_2^+ levels in even-even nuclei with $60<A<150$ and $190<A<220$

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The hypothesis is advanced that the admixture and the phase relations of the $M1$ and $E2$ radiation in $2_2^+ \to 2_1^+$ transitions are connected with the difference in the degrees of rigidity of the proton and neutron systems in spherical even-even nuclei. A correlation is obtained between the ratio $B(E2,\ 2_2^+ \to 0_0)/\ B(E2,\ 2_2^+ \to 2_1^+)$ and the level engery difference $E(0_1^+) - E(2_2^+)$.

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The de-excitation of the 2_2^+ levels of even-even "spherical" nuclei was considered in many papers [1–3]. Recently, data on the mixture of $M1$ and $E2$ radiation $\delta = \pm\sqrt{E2/M1}$ were tabulated by Krane [3,4]. Figure 1 shows the values of $1/\delta$ in $2_2^+ \to 2_1^+$ transitions of the considered nuclei as functions of the number of neutrons. The figure shows in addition the values of $1/\delta$ of the considered nuclei. The figure shows in addition the dependence of $1/\delta$ on the number of neutrons for $2_\gamma^+ \to 2_1^+$ transitions from the γ-vibration bands of nonspherical nuclei, which we do not consider here. The values of $1/\delta$ for fixed Z are connected by lines. It is important to note that in the scale assumed by us for $1/\delta$ the largest characteristic changes are due not to the reduced probability of the transition $B(E2)$, but to $B(M1)$. Attention is called to the fact that $1/\delta$ varies systematically with N in many elements, thus apparently indicating a collective (multiparticle) formation of not only the electric-quadrupole but also the magnetic-dipole matrix element of the $2_2^+ \to 2_1^+$ transitions far from the magic numbers. The character of the variation of $1/\delta$ and of its sign makes it possible to advance the hypothesis that the sign is positive if $B(M1)$ is determined by the protons (the neutrons are better packed near the magic numbers with respect to N) and is negative if $B(M1)$ is determined by the neutrons (the

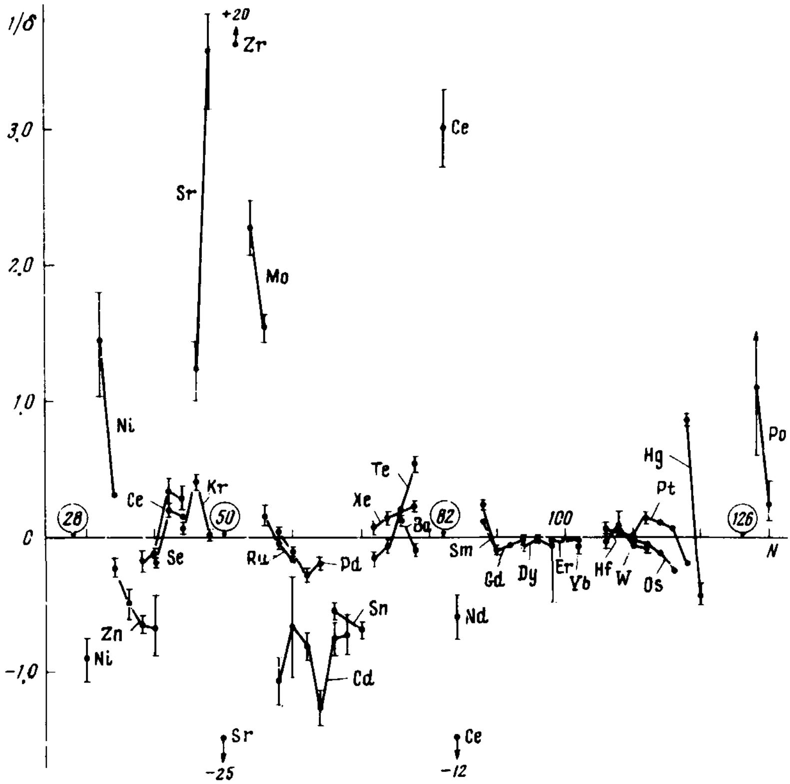

FIG. 1. Dependence of $1/\delta$ on the number of neutrons in the nucleus in $2_2^+ \to 2_1^+$ transitions, and for nonspherical nuclei in $2^+ \to 2_1^+$ transitions.

protons are closer packed). The change of sign is probably connected with change of the phase of the magnetic transition and is due to the opposite signs of the gyro-magnetic ratios of the neutron and proton. If this hypothesis is true, then the value of $1/\delta$ should give us an idea of the difference between the degrees of rigidity of the neutron and proton systems in the nucleus, and of the difference between their contributions to the collective motions of the nuclear surface. Particular interest attaches to the nuclei ^{88}Sr and ^{142}Ce, which are nearly magic in N, and in which large negative values of $1/\delta$ are observed. It is possible that the change of sign in these nuclei is connected either with the change of the phase for the $E2$ transition or with the change of the properties of the nuclear surface (the level 3^- in the nuclei ^{88}Sr and ^{142}Ce drops to the energy of the 2_2^+ level).

From an examination of the level schemes of the nuclei it follows that only a rough qualitative correlation is observed between the values of $1/\delta$ and of $[E(2_3^+) - E(2_2^+)]/E(2_1^+)$, where E is the energy of the corresponding level. Values of $1/\delta$ close to zero are observed as a rule in nuclei in which the two-phonon triplet is most isolated from the other levels. At the same time it has been

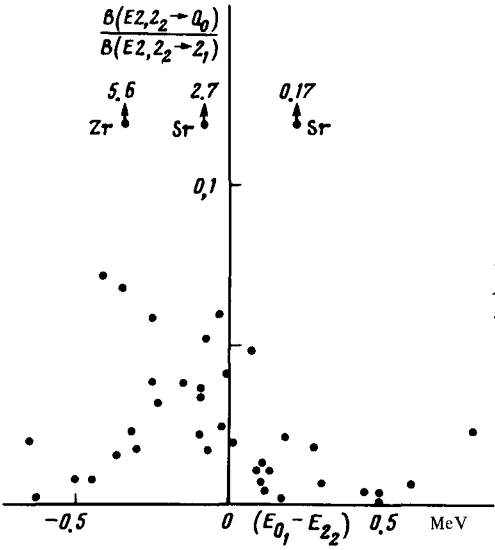

FIG. 2. Dependence of the ratio $B(E2, 2_2^+ \rightarrow 0_0)/B(E2, 2_2^+ \rightarrow 2_1^+)$ on $E(2_2^+) - E(0_1^+)$.

found that the ratio $B(E2,\ 2_2^+ \rightarrow 0_0)/B(E2,\ 2_2^+ \rightarrow 2_1^+)$ does not correlate in the general case with quantity $1/\delta$ but, as shown in Fig. 2 for nuclei with $60 < A < 150$, a certain correlation is observed between this ratio and $E(0_1^+) - E(2_2^+)$. For many elements this correlation can be clearly traced as the number of neutrons varies. The explanation of the last fact possibly lies in the influence of the position of the two-quasiparticle state 0^+ on the de-excitation of the 2_2^+ level to the ground state.

An examination of the de-excitation of the higher-lying levels 2^+ shows that their decay scheme can serve as a good indicator of the degree of softness of the nucleus: the breaking of the rigid coupling between the two-quasiparticle and the surface (collective) motions in the nucleus, which manifests itself primarily in an excess of $B(M1, 2^+ \rightarrow 2_1^+)$ over $B(E2, 2^+ \rightarrow 0_0)$ and $B(E2, 2^+ \rightarrow 2_1^+)$. In magic nuclei ($^{110-116}$Cd, ^{150}Sm), in which the 0_1^+, 0_2^+, and 3_1^- levels drop very low, a strong predominance of the probability of the $M1$ transitions over the $E2$ transitions sets in already at 2—2.5 MeV. From the data on the γ spectra from the $(n\gamma)$ reaction it is known that the probabilities of the $M1$ transitions greatly exceed the probabilities of the $E2$ transitions for practically all the nuclei in the case of de-excitation of states with energies 6—8 MeV.

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