Configurational splitting of the giant dipole resonance of nuclei of the 2*s*2*d* shell

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The scale of the configurational splitting of the giant dipole resonance—an energy splitting of the dipole transitions of nucleons from outer and inner nuclear shells—is determined for nuclei of the 2*s*2*d* shell through an analysis of experimental data. This splitting is 10–12 MeV for the nuclei ^{23}Na, ^{24}Mg, ^{27}Al, and ^{28}Si.

The configurational splitting of the giant dipole resonance of light nuclei ($5 < A < 40$) can be summarized by saying that during the absorption of electric dipole ($E1$) γ rays by the nucleus the transitions of nucleons from the closed inner shell into the partially filled outer shell (group B) are strongly shifted (from 4–5 to 10–12 MeV, for various nuclei) up the energy scale from transitions from the partially filled outer shell to a higher-lying, completely vacant shell (group A).[1,2] For nuclei of the 2*s*2*d* shell ($16 < A < 40$), the phenomenon is explained by Fig. 1. In addition to the two well-known types of splitting of the giant dipole resonance, amounting to several MeV, i.e., the splitting due to deformation, which is characteristic of nonspherical nuclei, and the deformation in isospin, which is characteristic of nuclei in which the number of neutrons is not equal to the number of protons, there is accordingly yet another, fundamentally new type of splitting of the giant dipole resonance, with a scale value of about 10 MeV.

Neudatchin and Shevchenko[3] have predicted the existence of a configurational splitting of the giant dipole resonance in nuclei of the 2*s*2*d* shell. The first attempts to experimentally test the idea of a configurational splitting of the giant dipole resonance of nuclei of the 2*s*2*d* shell were undertaken about 20 years ago (Ref. 4, for example). It was shown that the nature of the nucleon decay of the giant dipole resonance of nuclei in this region agrees with the representation of the occurrence of a configurational

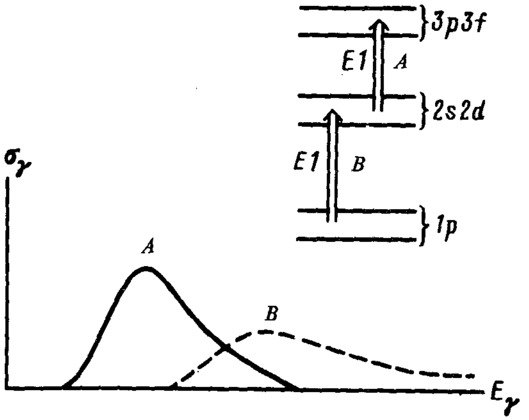

FIG. 1. Configurational splitting of the giant dipole resonance of nuclei of the $2s2d$ shell.

splitting. However, a proof that this phenomenon occurs and the establishment of its magnitude required systematic experiments to determine the energy dependence of the cross sections for photonucleon reactions accompanied by the production of final nuclei in $(2s2d)^{-1}$ and $(1p)^{-1}$ hole states with respect to the ground state of the target nucleus (the final states are produced in these hole states after the breakup, accompanied by the emission of an excited nucleon into the continuous spectrum of the partial-hole configurations which form from transitions *A* and *B*). Such experiments, which only comparatively recently have become feasible, have been carried out for a group of nuclei in the $2s2d$ shell at the Scientific-Research Institute of Nuclear Physics at Moscow State University.[5-10] These experiments make it possible to decompose the giant dipole resonance of the nuclei in this region into components linked with $2s2d \to 3p3f$ transition (group *A*) and $1p \to 2s2d$ transition (group *B*; the decomposition procedure is described in Ref. 2) and to draw definite conclusions regarding the existence and magnitude of the configurational splitting.

Figure 2 shows the results of the decomposition of the experimental photoabsorption cross sections σ_γ for the nuclei ^{23}Na, ^{24}Mg, ^{27}Al, and ^{28}Si for the transitions of types *A* and *B*. As σ_γ we use both the raw data on the photoabsorption cross sections[11,12] and the sum of the experimental photonucleon cross sections.[13] Analysis of the cross sections for photonucleon reactions accompanied by the filling of $(2s2d)^{-1}$ and $(1p)^{-1}$ hole states[2] shows that the component of the giant dipole resonance due to $2s2d \to 3p3f$ transitions degenerates to 30–35 MeV (see also Fig. 2), and a high-energy region of the giant dipole resonance (30–35 MeV) forms essentially entirely from $1p \to 2s2d$ transitions.

It can be seen from Fig. 2 that the main transitions of group *B* are shifted markedly up the energy scale from the main transitions of group *A*; in other words, a configurational splitting of the giant dipole resonance does occur. The magnitude of this splitting is found as the difference between the centers of gravity of the corresponding components of σ_γ. The positions of the centers of gravity are shown by the arrows in Fig. 2. The magnitude of the configurational splitting of the giant dipole resonance for ^{23}Na is 10–11 MeV; that for ^{24}Mg is about 9 MeV; and that for ^{27}Al and ^{28}Si is $\approx$ 12–13 MeV. For the nuclei of the $2s2d$ shell, the configurational splitting of the giant

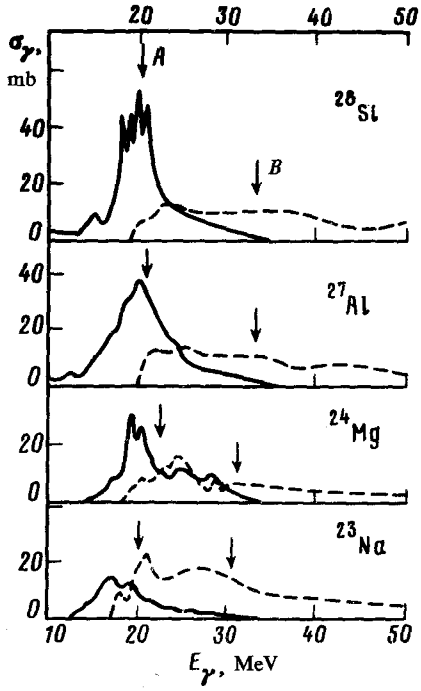

FIG. 2. Results of a decomposition of the experimental photoabsorption cross sections into components due to dipole transitions of nucleons from different shells. Solid lines—Transitions from the outer shell (group *A*); dashed lines—transitions from the inner shell (group *B*). The arrows show the centers of gravity of the corresponding groups.

dipole resonance is thus large ($\approx$9–12 MeV), greater than the other types of splitting of the giant dipole resonance. It can also be seen from Fig. 2 that the relative importance of the transitions of group *A* increases with increasing number of nucleons. This trend is a consequence of the filling of the outer shell.

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