M1 RESONANCE IN sd-SHELL NUCLEI

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γ-Decay of a resonance-like structure observed in the reactions of radiative capture of protons by ^{21}Ne, ^{22}Ne, ^{25}Mg, ^{26}Mg, ^{29}Si, ^{30}Si, ^{33}S, ^{34}S, and ^{36}S nuclei is studied. The M1 resonance built on the ground state of ^{22}Na, ^{23}Na, ^{26}Al, ^{27}Al, ^{30}P, ^{31}P, ^{35}Cl, and ^{37}Cl is identified. The position of the M1 resonance is explained taking into account pairing forces.

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Having studied γ-decays of the resonance-like structures observed in the reactions of radiative capture of protons by ^{21}Ne, ^{25}Mg, ^{29}Si and ^{33}S nuclei, we identified for the first time the magnetic dipole resonance (MDR) built on the ground states of the odd-odd 4N+np ^{22}Na, ^{26}Al and ^{30}P nuclei and performed the search for MDR in ^{34}Cl nuclei [1,2]. The position of the center-of-gravity (COG) of MDR ($E_{cg}=\Sigma_k E_k B_k(M1)/\Sigma_k B_k(M1)$) in these nuclei differs from that in 4N nuclei by 3 MeV (Fig. 1) and , in fact, does not depend on mass number A (it is usually thought that this dependence must be of the form $E_{c.g}=40\cdot A^{-1/3}$).

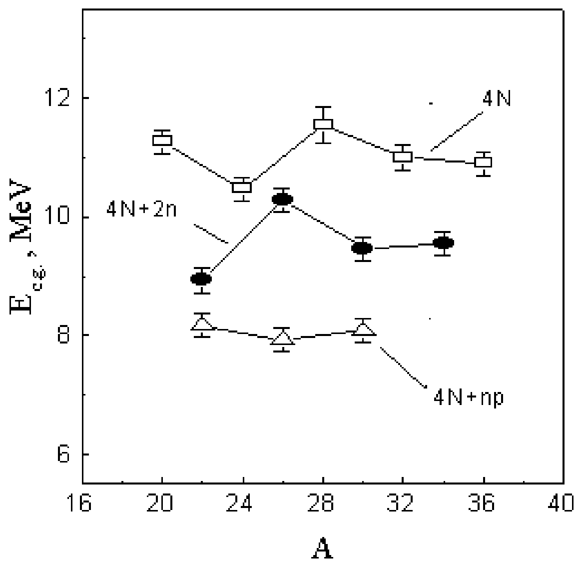

Fig. 1. *The positions of the COG of M1-resonance for even nuclei of sd-shell. Open square and triangle shows data from [7]*

We explained the new fact by assuming the existence of the triplet neutron-proton pairing. The joint analysis of the MDR total strength and position in 4N, 4N+2n and 4N+np nuclei shows that the formation of MDR in these nuclei is strongly influenced by the valence nucleons and that the MDR COG is determined not only by the energy of spin-orbit splitting but also by the strengths of both the nn(pp)-pairing and the np-pairing as well. The similar analysis for odd nuclei shows that the position of MDR COG in these nuclei depends on the state of odd particle: $d_{5/2}$ or $d_{3/2}$. The position of MDR COG in the first case must be in the region of excitation energies of 5…6 MeV because this position is determined by the energy of spin-orbit splitting only. In the second case, the nn- or pp-pairs from $d_{5/2}$-subshell can participate in the formation of MDR and the position of MDR COG in odd nucleus will then slightly differ from that position in neighboring even nuclei with mass number (A−1), i.e., it will be situated in the region of excitation energies of 8…10 MeV.

Here γ-decays of the resonance-like structures observed in ^{22}Ne, ^{26}Mg, ^{30}Si, ^{34}S, ^{36}S(p,γ)^{23}Na ^{27}Al, ^{31}P, ^{35}Cl, ^{37}Cl reactions are investigated in the region of excitation energies of 9…11 MeV [3-6]. The measurements of the excitation function of these reactions are carried out in the region of energies of accelerated protons E_p=1…3 MeV. These measurements were held on the electrostatic accelerator of National Scientific Center "Kharkov Institute of Physics and Technology". The spin and parity of the studied resonances, the branching coefficients, the multipole mixing coefficients and the probabilities of γ-transitions are determined from the analysis of the decay schemes. The analysis of the angular distributions involved determining the spins of resonance states and the multipole-mixing coefficients for γ-rays (δ) by minimizing the quantity

$$\chi^2 = \sum_n \left[\frac{A_0 W^{\text{theor}}(\theta_n) - W^{\exp}(\theta_n)}{\Delta W^{\exp}(\theta_n)} \right]^2 . \qquad (1)$$

where $W^{theor}(\theta) = \Sigma_k Q_k \rho_{k0} F_k(J_1,J_2,L,\delta) P_k$ is the theoretical angular distribution of photons for the transition between the initial and final states with spins J_1 and J_2, $W^{exp}(\theta)$ and $\Delta W^{exp}(\theta)$ are the experimental

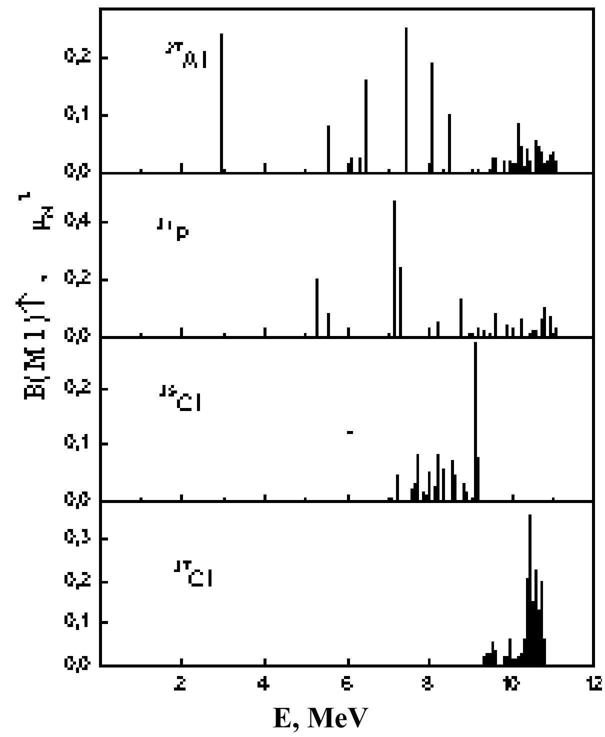

Fig. 2. *M1-resonance for odd nuclei of sd-shell*

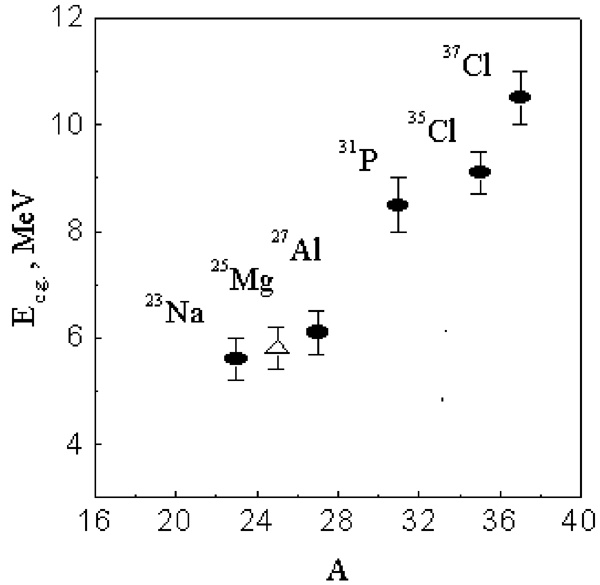

Fig. 3. *The positions of the COG of M1-resonance for odd nuclei of sd-shell. Open triangle shows data from [7]*

data and the corresponding statistical uncertainty, A_0 is the normalization constant, $Q_к$ is a coefficient accounting finite dimensions of the detector, ρ_{k0} is an element of the statistical tensor, n is the number of experimental points (angles). The fitting procedure for odd nuclei differed from that for even nuclei: for odd nuclei the parameters of the statistical tensor were calculated and the multipole-mixing coefficient (δ) remained the only fitting parameter. The spin values of resonances at hand were defined, in general, via analysis of transitions to the ground state. The parities were defined based on the comparison of probabilities of electromagnetic transitions of different multipolarity with recommended upper limits of the given values [7]. The reduced probability of γ-transition B(M1) was calculated using the expression

$$B(M1)\uparrow=86{,}6\cdot b\cdot S(eV)/(2J+1)E^3_\gamma, \qquad (2)$$

where b is the branching coefficient of γ-transition, J is the spin of initial state, constant S is in eV, and E_γ is the energy of γ-transition in MeV. All the studied transitions are mainly the M1-transitions with the small admixture of E2-multipolity.The obtained distributions of the strengths of M1-transitions in ^{23}Na [6], ^{27}Al, ^{31}P, ^{35}Cl, ^{37}Cl nuclei have resonance character (Fig. 2). The positions of MDR COG in ^{23}Na, ^{25}Mg and ^{27}Al are equal to 5.6±0.2, 5.8±0.2 and 6.1±0.2 MeV respectively (Fig. 3) and are situated in the region of excitation energies which is expected for nuclei with unclosed $d_{5/2}$-subshell, i.e. they are defined only by the energy of spin-orbit splitting. The MDR COG built on the ground states of ^{31}P, ^{35}Cl, ^{37}Cl nuclei are equal to 8.5±0.3, 9.1±0.1 and 10.5±0.2 MeV respectively and are situated in the region of excitation energies expected for the odd nuclei with closed $d_{5/2}$-subshell. In other words the position of MDR COG for these nuclei are affected by the magnitude of nn(pp)-pairing in $d_{5/2}$-subshell.

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