Calculation of $E1$ radiative strength functions in semimagic nuclei

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The $E1$ radiative strength functions of a number of semimagic nuclei are calculated within the framework of a semimicroscopic approach, and the results are compared with the experimental data. The calculations do not employ free parameters. A good description of the experimental data was obtained.

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We have calculated the $E1$ radiative strengths of a number of semimagic nuclei within the framework of a semimicroscopic approach. Good agreement with the experimental data was obtained.

The model developed in[1] was applied in[2] to a description of the fragmentation of single-phonon states of spherical nuclei in terms of the two-phonon states. The Hamiltonian of the model contains an isoscalar and an isovector component of the residual multipole forces. We use the formalism developed in[2] to calculate the $E1$ strength functions for transitions from the ground states of even-even spherical nuclei. The wave function of the neutron resonance is taken in the form

$$\Psi_\nu(JM) = \{\sum_i R_\nu(J_i)Q^+_{JMi} + \sum_{\substack{\lambda_1 i_1 \\ \lambda_2 i_2}} P^{\lambda_1 i_1}_{\lambda_2 i_2}(J_\nu)[Q^+_{\lambda_1\mu_1 i_1} Q^+_{\lambda_2\mu_2 i_2}]_{JM}\}\Psi_0 , \tag{1}$$

where Q^+_{JMi} is the phonon production operator and Ψ_0 is the wave function of the ground state. Following,[2,3] we use for the calculation of the radiative strength functions a method that permits the mean values to be calculated without solving the secular equations. The strength function for the $E1$ transitions to levels in the energy interval $(\eta-\Delta/2,\eta+\Delta/2)$ is of the form

$$b(E1,\eta) = \frac{1}{2\pi}\sum_\nu \frac{\Delta}{(\eta-\eta_\nu)^2+\frac{\Delta^2}{4}} B(E1.0^+_{gs}\to 1^-_\nu). \tag{2}$$

Here $B(E1)$ is the reduced probability of the transition from the ground state to the state described by the wave function (1). The radiative width for the $E1$ transitions from the levels 1^- to the ground state is defined as

$$\Gamma_{\gamma_0} = 0.35E_\gamma^3 B(E1,\uparrow)\,\text{eV}, \tag{3}$$

where $B(E1,\uparrow)$ is determined from (2) and is expressed in units of $e^2\text{F}^2$, while E_γ is in MeV. A widely used definition of the radiative strength functions is

TABLE I.

nucleus	E_γ, MeV	$S_\gamma \times 10^5$		
		Experiment	Reference	Calculation
^{56}Fe	11,2	3.95	[7]	3,5
	—	3.5	[8]	—
^{90}Zn	8,7	4,3	[4]	4,5
	10.0	10,2	—	48
	11,3	18,1	—	24
	11,6	22,9	—	20.5
	11,9	24,0	—	25,0
	12,1	25,3	—	40,3
Sn	6.2	1,4	[4]	1.8
	6,4	3,2	—	2,0
	7.0	3,5	—	3.8
	8,6	12,9	—	14,7
	9,1	13,7	—	35.9
^{138}Ba	8,6	6,5	[5]	9,9
^{140}Ce	9,08	4,2	[9]	3,7

$$S_\gamma = \sum_{\Delta E} \Gamma_{\gamma_0} / \Delta E, \tag{4}$$

where Γ_{γ_0} and ΔE are in eV.

The results of our calculations and the corresponding experimental data are listed in Table I. The parameters used in the calculations were the same as

TABLE II.

Nucleus	Experiment		Calculation	
	η, MeV	Γ_{γ_0}, MeV	η, MeV	Γ_{γ_0}, MeV
^{118}Sn	6.988	128 ±3	6,38	534
^{120}Sn	7,696	70 ± 20	7,78	775
^{140}Ce	5,66	12 ± 2	5,74	158

in[2], and the average interval was $\Delta E = 0.4$ MeV. The values of S_γ given for Sn are averaged over the even-even isotopes $^{116-124}$Sn, just as in the experimental paper. [4] As seen from Table I, we describe quite well the average radiative strength functions. It should be noted that the results of the calculations depend on the choice of the averaging interval. Thus, for example, in the case of ^{138}Ba, when ΔE is changed from 0.5 to 2.0 MeV, the value of $S_\gamma \times 10^5$ changes from 9.9 to 4.4. The experimental values, with allowance for the errors, [5] lie in the range $S_\gamma \times 10^5 = 5.8$—9.8. Thus, variation of the averaging interval does not lead to noticable changes of our results. For the remaining nuclei of Table I, the values of S can change by a factor of 1.5—2 when ΔE changes from 0.5 to 2.0 MeV.

The (γ,γ') reactions are widely used to measure the partial widths $\Gamma_{\gamma 0}$ in the excitation of individual levels. Table II lists the experimental data[6] on $\Gamma_{\gamma 0}$ and the results of our calculations. The calculated values of $\Gamma_{\gamma 0}$ are larger by approximately one order of magnitude than the experimental ones. This discrepancy is not surprising, since we calculate in essence the sum of $\Gamma_{\gamma 0}$ in an energy interval, while the experimental conditions are such that $\Gamma_{\gamma 0}$ is measured for one randomly chosen level. It is of great interest to investigate the (γ,γ') reactions with excitation of states in an energy interval of several hundred keV.

Summarizing, we can state that we are able to calculate adequately the radiative strength functions at excitation energies on the order of the neutron binding energy B_n, without using any free parameters. The parameters of the Hamiltonian are fixed in the study of the low-lying states and giant resonances. [2] It was not obvious beforehand that at energies on the order of B_n it will be possible to describe the experimental data. The value of the $E1$ radiative strength functions in semimagic nuclei is determined for the most part by the 1^- states that lie near B_n and change little when account is taken of the giant dipole resonance.

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