Nuclear Incompressibility Coefficient within Fermi Liquid Drop Model

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New experimental data for the isoscalar giant monopole (ISGMR) and dipole (ISGDR) resonances and inability of the self-consistent Hartree-Fock (HF) random phase approximation (RPA) calculations to simultaneously reproduce the experimental values of the centroid energies E0, and E1 and widths $\Gamma 0$, and $\Gamma 1$, of the ISGMR and ISGDR, respectively, and the experimental value E1/E0, have renewed interest in research of theoretical description of multiple particle-hole excitation. We have previously shown that experimental value of ratio E1/E0 can be reproduced by the introduction of collisional damping into the Fermi Liquid Drop Model (FLDM). However, the absolute values of the centroid energies E0, and E1, and the widths $\Gamma 0$, and $\Gamma 1$, obtained from FLDM with collisional FSD, are overestimated with respect to experimental data.

To address this issue we study the dependence of the energies for ISGMR and ISGDR in ^{208}Pb as functions of the nucleus incompressibility coefficient K_A. We start from the fluid dynamic equations of motion for the viscous Fermi liquid [1]. Within the FLDM, the eigenfrequency ω of the compression modes satisfies the dispersion equation

$$\omega^2 - c_0^2 q^2 + i\omega\gamma q^2 = 0, \qquad c_0^2 = \left(K_A + 12\mu/\rho_0\right)/9m, \qquad \gamma = 4\nu/3\rho_0 m, \tag{1}$$

where ρ_0 = 0.17 fm^{-3} is the bulk particle density corresponding to the sharp radius $R_S = 1.12A^{1/3}$ fm, and m is the nucleon mass. The transport coefficients μ and viscosity ν in Eq. (1) are due to the Fermi surface distortion (see Ref. [1]) and are given by

$$\mu = \mathrm{Im}\left(\omega\tau/\left(1 - i\omega\tau\right)\right)\ P_{eq}, \qquad \nu = \mathrm{Re}\left(\tau/\left(1 - i\omega\tau\right)\right)\ P_{eq}, \tag{2}$$

where P_{eq} is the equilibrium pressure in the nuclear interior. The memory effect is introduced into the model by the dependence of transport coefficients on the excitation eigenfrequency through the relaxation time τ

$$\tau = 4\pi^2\beta\ \hbar\big/\left(\hbar\,\mathrm{Re}(\omega)\right)^2 . \tag{3}$$

The wave number q in Eq. (1) is derived by the boundary conditions on the free surface of the nucleus. Solving appropriate secular equations for boundary conditions of isoscalar monopole and dipole excitations we obtain centroid energies and widths of compression excitations. We have found that the damping coefficient β = 0.65 provides a good fit of calculated value of the ratio E1/E0 to the experimental value. Then, by varying the nucleus incompressibility K_A in Eq. (1) as a parameter we studied behavior of E1, and E0, appropriate widths $\Gamma 0$, and $\Gamma 1$, and compared the nucleus incompressibility coefficient K_A with the scaling approximation value K_S, obtained with ISGMR energy taken as described in [2]:

$$K_S = \frac{m\langle r^2 \rangle}{\hbar^2}\left(\mathrm{E0}^2 + 3(\Gamma 0/2.35)^2\right). \tag{4}$$

Assuming a Fermi density distribution, the rms-radius was calculated using

$$\langle r^2 \rangle = \tfrac{3}{5} R^2 \left[1 + \tfrac{10}{3}(\pi a/R)^2 + \tfrac{7}{3}(\pi a/R)^4\right] \Big/ \left[1 + (\pi a/R)^2\right], \tag{5}$$

where a = 0.53 fm and R are the diffuseness and half radius of the charge distribution, corresponding to R_S. Results of the calculation for ^{208}Pb with $\beta = 0.65$ are presented in Table I. Results of our calculations show that within the current model, the experimental values of E0, and E1, and E1/E0 for ^{208}Pb are very well reproduced.

Table I. Centroid energies and widths of ISGMR and ISGDR, and the nucleus incompressibility K_S for ^{208}Pb as a function of input coefficient K_A, in MeV

K_A	E0	E1	$\Gamma 0$	$\Gamma 1$	K_S
130.0	12.61	20.52	2.76	7.06	120.78
135.0	12.83	20.76	2.81	7.09	125.00
140.0	13.04	20.98	2.86	7.10	129.30
145.0	13.26	21.19	2.91	7.10	133.67
150.0	13.46	21.43	2.96	7.12	137.67
155.0	13.67	21.65	3.01	7.12	142.17
Exp.*	13.97 ± 0.20	22.20 ± 0.30	2.88 ± 0.20	9.39 ± 0.35	145.96

* Ref. [4].

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