M1 scissors mode for gamma emission spectrum and its effect

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1. Introduction

Up to now, the anomalous bumps which appear in low energy gamma have been described by introducing the E1 pygmy resonance [1, 2]. But this method has difficulty to describe the bumps, which appear in the rare earth and actinide nuclei, because they are deformed. In order to obtain the spectra for such deformed nuclei, we have to consider another kind of electromagnetic transition, M1 scissors mode excitation [3, 4]. By adding M1 scissors mode as well as E1 pygmy resonance into giant multipole resonance for Gd and U isotopes, which have the experimental data, and analyzing with the Hauser-Feshbach statistical model, we obtained improved gamma emission spectra.

2. Methodology

2.1General description

The EMPIRE-II [5] based on the Hauser-Feshbach statistical model [6] was employed for the calculation of the capture cross sections and gamma emission spectra. We needed the level density parameters and transmission coefficients to employ the Hauser-Feshbach statistical model. As our objective was to analyze the anomalous bumps in the view point of the M1 scissors mode excitation, we adopted simple models for the nuclear level density and optical potential, etc.

The Gilbert-Cameron method [7] was adopted for the nuclear density and its parameters were searched from RIPL-2 [8]. To calculate the transmission coefficient for particles, we adopted the spherical optical potential. Its parameters taken from RIPL-2 were tuned in order to reproduce the experimental total and elastic cross sections.

2.2 M1 scissors mode excitation

As for the transmission coefficient of gamma rays, we employed different profile functions for each transition. We used the Kopecky-Uhl formula [9] for E1 transition and the Brink-Axel one for M1 and E2 ones. In this work, other transitions were not considered due to their weak effect for the total spectrum.

In order to consider the E1 pygmy resonance and M1 scissors mode, we added the E1 pygmy resonance into E1 transition and M1 scissors mode into M1 one. Their geometrical models are shown in Fig. 1.

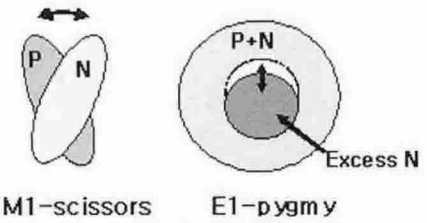

Fig. 1 M1 scissors mode and E1 pygmy resonance.

At previous work [2], we obtained the formula of the E1 pygmy resonance. As for M1 scissors mode, we took same method with E1 pygmy resonance. That is, M1 scissors mode having Brink-Axel form was added into M1 profile function as follows:

$$f_{scissors}(E_\gamma) = \frac{\sigma_s E_\gamma \Gamma_s^2}{(E_\gamma^2 - E_s^2)^2 + (E_\gamma \Gamma_s)^2}, \quad (1)$$

where E_s, σ_s, and Γ_s are the resonance energy, the peak cross section and the resonance width, respectively. The parameters were determined by fitting experimental data as the E1 pygmy resonance parameters were.

3. Result and discussion

Figure 2 show the effects of E1, E2 and M1 transition for the gamma emission spectra. As shown Fig. 2, the effect of E2 transition is very small for the total spectrum, and the E1 and M1 transitions are dominant. The low and high regions in the gamma spectra do not show good agreements with the experimental data because the statistical model is appropriate only in the medium region.

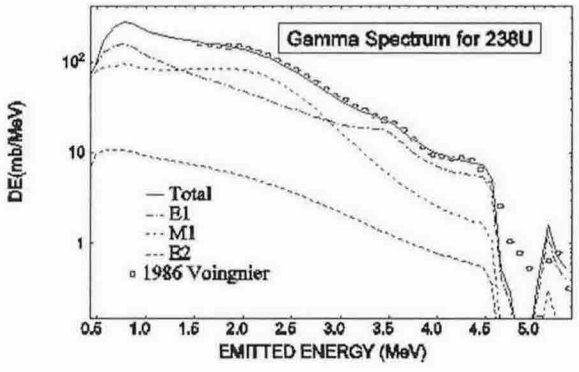

Fig. 2 Gamma spectra for U-238.

The medium region show good agreement with the experimental data by adding the M1 scissors mode and E1 pygmy resonance. We determined that the resonance

energy was 2.5 MeV for M1 scissors mode and 3.5 MeV for E1 pygmy resonance, assuming that the effect of the former is larger than that of the latter in the case of deformed nuclei.

4. Conclusion

We calculated the gamma emission spectra for Gd and U isotopes which are strongly deformed, and ascertained the effects of each electromagnetic transition for the total gamma spectra. After all, we could reproduce well the experimental data by employing the gamma strength function with both the E1 pygmy resonance and M1 scissors mode excitation.

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