Microscopic Description of Excitation of Isoscalar Giant Quadrupole Resonances in ^{28}Si, ^{40}Ca, ^{58}Ni, and ^{116}Sn by Inelastic Scattering of 240 MeV $\alpha-$Particles.

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An important aspect of the problem of identifying the presence of isoscalar giant monopole resonance (ISGMR) strength in inelastic $\alpha-$particle scattering spectra is the description of isoscalar giant quadrupole resonance (ISGQR) excitation. This is due to strong overlapping between ISGMR and ISGQR transition strength distributions. The experimental analysis of excitation of ISGQR in $\alpha-$particle scattering reactions is based upon the Distorted Wave Born Approximation (DWBA) and the collective model shape of the isoscalar quadrupole (E2T0) transition density. The so-called Bohr-Mottelson shape [1]

$$\delta\rho_{L=2}(r) = -\delta_{L=2}(E)\frac{d\rho_0(r)}{dr} \qquad (1)$$

is widely used to describe the radial part of the E2T0 transition density. The energy-dependent factor $\delta_{L=2}(E)$ is determined by fitting measured inelastic cross sections and the amount of E2T0 energy weighted sum rule (EWSR) concentrated in a given state E_R is found by comparing this factor with the one corresponding to a 100% of the E2T0 EWSR [1]:

$$\delta_{L=2}^{100\%EWSR}(E_R) = \left[\frac{25}{8}\frac{2\pi\hbar^2}{mAE_R}\frac{\langle r^2\rangle}{\langle r\rangle^2}\right]^{1/2}. \qquad (2)$$

Here we investigate how the use of microscopic instead of collective model densities may influence the conclusions regarding the strength distributions of ISGQR. We obtain microscopic ground state and transition densities by performing self-consistent Hartree Fock (HF) Random Phase Approximation (RPA) calculations. We obtain angular distributions of inelastically scattered $\alpha-$particles corresponding to E2T0 excitations of ^{28}Si, ^{40}Ca, ^{58}Ni, and ^{116}Sn by using the folding model DWBA approach. The optical and transition potentials are found by convoluting the ground state and transition densities with a two-body $\alpha-$nucleon interaction of density dependent Gaussian type. The parameters of the $\alpha-$nucleon interaction are obtained by fitting measured angular distributions of 240-MeV $\alpha-$particles elastically scattered on ^{28}Si, ^{40}Ca, ^{58}Ni, and ^{116}Sn targets [2, 3, 4, 5].

Figure 1 illustrates our results for the case of E2T0 excitation of ^{116}Sn. The middle panel of the figure shows double differential cross sections for the first peak of E2T0 angular distribution calculated using microscopic (RPA) transition density. The solid (dashed) line in the lower panel of the figure represents the cross sections for the first peak of E2T0 angular distribution when microscopic (collective model) transition densities are normalized to a 100% of the E2T0 EWSR. The solid line in the upper panel shows the ratio between the curve in the middle panel and the solid line in the lower panel. This is the same percentage of E2T0 EWSR per unit energy in ^{116}Sn as one obtains from HF-RPA calculations. The dashed line in the upper panel shows the ratio between the curve in the middle panel and the dashed line in the lower panel. This is the percentage of E2T0 EWSR per unit energy reconstructed from the cross section analysis using collective model shape of the E2T0 transition density. As can be seen, the differences between the actual and the reconstructed E2T0 EWSR are noticeable. An interesting feature of the reconstructed E2T0 EWSR is the appearance of a well pronounced high energy overtone state which is not noticeable in the actual E2T0 EWSR energy distribution. This is solely due to the difference in shapes between the collective model Eq.1 and microscopic transition densities. Overall, the energy distribution of the E2T0 EWSR obtained from the cross section analysis using collective model transition density is enhanced compared to the actual one which leads to the overestimation of the total E2T0 EWSR in this type of analysis by 30% for the case of ^{116}Sn. Similar results where obtained for other nuclei and are summarized in Table 1.

In summary, we investigated the differences between the $\alpha-$particle scattering cross section analysis based on using microscopic versus collective model transition densities for E2T0 excitations in ^{28}Si, ^{40}Ca, ^{58}Ni, and ^{116}Sn nuclei. It follows from our results that collective model based analysis tends to overestimate the E2T0 EWSR by up to 30%. Moreover, at higher energies this analysis may lead to appearance of overtone states whose strength is greatly enhanced compared to the strength which might be actually present.

Table 1. Percentages of the E2T0 EWSR exhausted by the RPA strength distribution and the one reconstructed from E2T0 cross sections using collective model transition density.

Nucleus	Energy range (MeV)	Actual (RPA) (%)	Reconstructed (%)
^{28}Si	10–30	77	110
^{40}Ca	10–30	94	122
^{58}Ni	10–30	82	107
^{116}Sn	10–30	83	114

References

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Figure 1. Recostruction of the ISGQR EWSR from inelastic *alpha*−particle cross section for ^{116}Sn. For explanation of the figure, see text.