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GIANT DIPOLE RADIATION AND ISOSPIN MIXING IN HOT NUCLEI WITH $A = 32$–60*

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High-energy γ-ray spectra from statistical decay of the Giant Dipole Resonance in ^{60}Zn and ^{61}Zn nuclei were measured and analysed. The GDR parameters and the isospin mixing probability for ^{60}Zn at around 50 MeV excitation energy were deduced from both experiments. This result and the previous results obtained for ^{32}S, ^{36}Ar, ^{44}Ti nuclei allowed to establish the dependence of the isospin mixing on the atomic number Z.

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1. Introduction and experimental method

Statistical decay of the Giant Dipole Resonance (GDR) built on highly excited states populated in heavy-ion fusion reactions may be used as a tool to study the isospin mixing in hot self-conjugate nuclei [1–4]. The experimental method of extracting the isospin mixing probability α^2, which describes the amount of the admixture of states with isospin T' into the excited state with isospin T [5], was invented by Harakeh [1] and improved by Behr [2]. It is based on the measurements of the high-energy γ-ray yields from the statistical decay of the GDR built in neighbouring $N = Z$ and $N \neq Z$ compound nuclei at similar excitation energy. The GDR yield from the decay of the self-conjugate compound nuclei, when populated by $T = 0$ reaction channel, depends strongly on the isospin mixing due to the isovector character of the GDR, the GDR yield for $N \neq Z$ compound nuclei does not. The isospin mixing probability α^2 in $N = Z$ nuclei may be extracted by comparing these yields with the statistical model calculations.

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During the last decade the excitation energy dependence of the isospin mixing probability in hot ^{26}Al and ^{28}Si light compound nuclei have been studied using this method [2]. Strong decrease of α^2 with the excitation energy in the range $E_x = 20$–65 MeV was found, in agreement with theoretically predicted restoration of isospin symmetry in hot nuclei [6, 7]. For nuclei in the ground state, the dependence of the isospin mixing probability on the atomic number Z was suggested [8]. An increase of α^2 with increasing Z may be expected also for nuclei at finite temperatures. In order to investigate the dependence of the isospin mixing probability on the atomic number of highly excited self-conjugate nuclei we have studied statistical GDR decay of ^{32}S [3], ^{36}Ar [4], ^{44}Ti [4], and presently, ^{60}Zn compound nuclei formed at similar excitation energies (temperatures) by $T = 0$ reaction channels: ^{20}Ne + ^{12}C, ^{12}C + ^{24}Mg, ^{20}Ne + ^{24}Mg, and ^{36}Ar + ^{24}Mg. The neighbouring compound nuclei with $N \neq Z$ at close excitation energy (temperature) were populated by reactions: ^{19}F + ^{12}C, ^{12}C + ^{25}Mg, ^{20}Ne + ^{25}Mg, and ^{36}Ar + ^{25}Mg. All experiments were performed with use of beams from the Warsaw Cyclotron and self-supporting isotopic enriched targets. Gamma rays from the decay of the compound nuclei studied were measured with the multidetector JANOSIK set-up [9]. Measured high-energy γ-ray spectra were fitted with CASCADE statistical model. A modified version of the CASCADE code including an isospin and parity, Reisdorf's formula for level densities, and experimental fusion cross-sections was used [1,2]. The isospin mixing was parameterised by the Coulomb spreading width $\Gamma_>^{\downarrow}$, assuming that $\Gamma_>^{\downarrow}$ is the same in neighbouring nuclei at a given excitation energy.

2. Results

The results presented in this section were newly obtained by a consistent analysis of the whole set of experimental data from all the reactions mentioned above. The high-energy γ-ray yields from the decay of $N \neq Z$ compound nuclei studied were fitted with the statistical model in order to extract the GDR parameters. In the first step it was assumed that these yields do not depend on the isospin mixing, so the calculations were done with no mixing. Taking into account that the GDR parameters should be very similar for nuclei close in mass and having the same excitation energy and spin, the extracted parameters were applied in the CASCADE calculations for neighbouring $N = Z$ nuclei. Such calculations were performed for a few different values of the Coulomb spreading width $\Gamma_>^{\downarrow}$, treated as the only one free parameter when comparing by the χ^2 test the calculated spectrum with the experimental data.

In order to increase the sensitivity to the isospin mixing we have also analysed the ratios of γ-ray cross-sections for the reactions forming $N = Z$ and $N \neq Z$ nuclei for the measured and calculated yields. The best value of $\Gamma^{\downarrow}_{>}$ corresponding to the minimum value of the χ^2 was found for each $N = Z$ nucleus studied. The extracted value of $\Gamma^{\downarrow}_{>}$ was then used in the new fitting procedure for the $N \neq Z$ neighbouring nucleus in order to obtain a new set of GDR parameters suitable for both neighbouring nuclei. The isospin mixing probability in self-conjugate nuclei was calculated from the formula [2]:

$$\alpha^2_{<} = \frac{\Gamma^{\downarrow}_{<}/\Gamma_{<}}{1 + \Gamma^{\downarrow}_{<}/\Gamma_{<} + \Gamma^{\downarrow}_{>}/\Gamma_{>}} \, .$$

It is worth to notice that the GDR parameters are not strongly dependent on the isospin mixing in investigated nuclei. Measured and calculated high-energy γ-ray spectra from the decay of ^{60}Zn and ^{61}Zn nuclei are presented in Fig. 1 together with extracted values of the GDR parameters and the value of the isospin mixing probability.

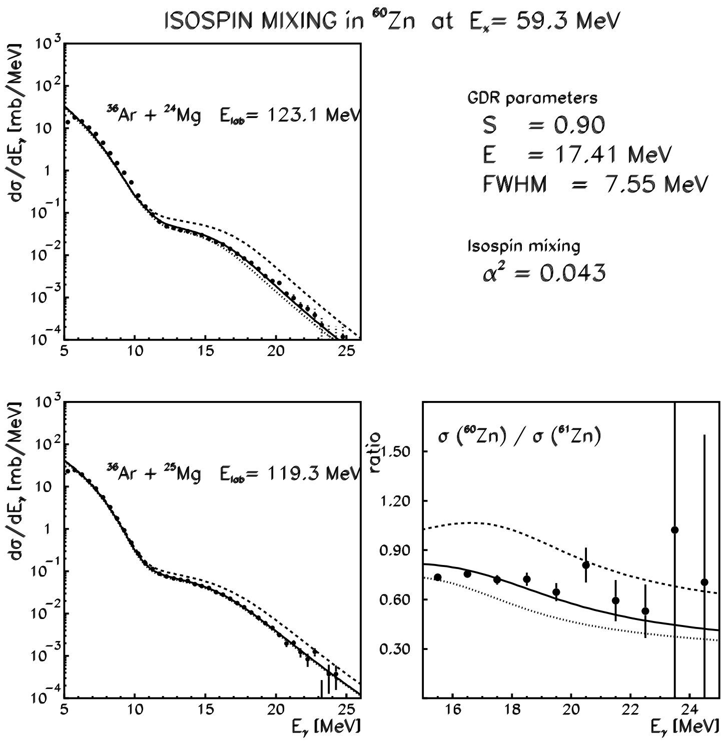

Fig. 1. Spectra of γ-rays emitted during the decay of ^{60}Zn (upper-left) and ^{61}Zn (bottom-left) and the ratios of these spectra (bottom-right). The curves CASCADE fit with different isospin mixing probability: no mixing (dotted curve, the lowest), extracted mixing (middle, solid curve) and full mixing (upper, dashed curve).

3. Conclusions

Consistent analysis of the measured γ-ray spectra for all reactions studied proves that the isospin mixing probability at high excitation in nuclei at similar temperature increases with increasing atomic number Z. In our experiments it was confirmed in the range of $Z = 16$–30 (Fig. 2).

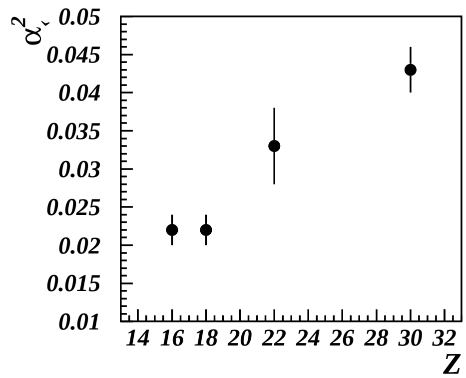

Fig. 2. Isospin mixing probability $\alpha^2_<$ dependence on atomic number.

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REFERENCES

[1] M.N. Harakeh, *et al.*, *Phys. Lett.* **B176**, 297 (1986).
[2] J.A. Behr, *et al.*, *Phys. Rev. Lett.* **70**, 3201 (1993).
[3] M. Kicińska-Habior, *et al.*, *Nucl. Phys.* **A731**, 138 (2004).
[4] E. Wójcik, *et al.*, *Acta Phys. Pol. B* **37**, 207 (2006).
[5] G.F. Bertsch, A. Mekjian, *Ann. Rev. Nucl. Sci.* **19**, 25 (1972).
[6] H.L. Harney, A. Richter, H.A. Weidenmüller, *Rev. Mod. Phys.* **58**, 607 (1986).
[7] H. Sagawa, P.F. Bortignon, G. Colo, *Phys. Lett.* **B444**, 1 (1998).
[8] J. Dobaczewski, I. Hamamoto, *Phys. Lett.* **B345**, 181 (1995).
[9] M. Kicińska-Habior, *et al.*, *Acta Phys. Pol. B* **28**, 189 (1997).