GIANT DIPOLE RADIATION AND ISOSPIN MIXING IN HOT LIGHT NUCLEI*

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Probability of isospin mixing at high excitation has been determined only for few nuclei. Thus, we attempted to extract the degree of isospin mixing in several light, self-conjugate compound nuclei at excitation energy around 50 MeV and study its dependence on atomic mass number. For this purpose we have studied the statistical decay of the Giant Dipole Resonance (GDR) built on excited states formed in heavy-ion fusion reactions. We have measured the ^{20}Ne + ^{12}C, ^{12}C + ^{24}Mg, ^{20}Ne + ^{24}Mg and ^{36}Ar + ^{24}Mg reactions populating $N = Z$ compound nuclei: ^{32}S, ^{36}Ar, ^{44}Ti, ^{60}Zn and the ^{19}F + ^{12}C, ^{12}C + ^{25}Mg, ^{20}Ne + ^{25}Mg and ^{36}Ar + ^{25}Mg reactions populating neighbouring compound nuclei with $N \neq Z$ at close excitation energy (temperature). Heavy-ion beams from the Warsaw Cyclotron have been used. High-energy γ-rays emitted in the reactions have been measured with the JANOSIK set-up. Measured spectra have been fitted with the CASCADE statistical model calculations assuming a Lorentzian GDR strength function.

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1. Introduction

The isospin mixing probability describes the amount of the admixture of states with isospin T' into the state with isospin T [1]. The state of isospin T is the mother state and the states with isospin T' give rise to the isospin impurity in the mother state by coupling to it. Such isospin violation exists

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because of the isospin non-conserving interactions, the main part of which is the isovector part of the Coulomb interaction. Isospin mixing at high excitation is still not well determined. All what is known is that the isospin mixing probability at high excitation should be small and decrease with the increase in excitation energy [2–4]. Thus, we decided to investigate this topic and examine isospin mixing dependence on the nuclear mass.

2. Experimental method

To obtain the isospin mixing probability of highly excited states the method originally proposed by Harakeh was used [5]. It consists of observation of the forbidden transitions during the γ-decay of the Giant Dipole Resonance (GDR) excited in self-conjugate compound nucleus. The GDR was excited in heavy-ion fusion reaction, by entrance channel with the isospin $T = 0$, populating mostly $T = 0$ states in $N = Z$ compound nucleus. The E1 transitions during the decay of the GDR, owing to their isovector character, may occur only to $T = 1$ states. There are not many states with isospin $T = 1$ available. Hence, the yield of high-energy γ-rays in the statistical decay of $N = Z$ compound nuclei should be suppressed, on the assumption that isospin is conserved. However, the observed yield is much larger than it is expected. It suggests that some admixture of states with isospin $T = 1$ into the states with isospin $T = 0$ in the initial compound nucleus does occur. In $N \neq Z$ neighbouring compound nuclei the isospin of initial state is not equal to 0, so that the E1 transition between states with the same isospin is allowed. Therefore the yield of high-energy γ-rays from $N \neq Z$ compound nucleus does not depend much on isospin mixing.

We have measured the ^{20}Ne + ^{12}C, ^{12}C + ^{24}Mg, ^{20}Ne + ^{24}Mg and ^{36}Ar + ^{24}Mg reactions populating $N = Z$ compound nuclei: ^{32}S, ^{36}Ar, ^{44}Ti, ^{60}Zn and the ^{19}F + ^{12}C, ^{12}C + ^{25}Mg, ^{20}Ne + ^{25}Mg and ^{36}Ar + ^{25}Mg reactions populating neighbouring compound nuclei with $N \neq Z$ at close excitation energy. For all those reactions we have studied statistical decay of the GDR.

The experiments were performed using JANOSIK set-up [6] consisting of the 25.4 cm $\times$ 29 cm cylindrical NaI(Tl) spectrometer surrounded by an anticoincidence plastic, ^{6}LiH and Pb shields. During the experiment the gain of the NaI crystal was controlled. The high-energy γ line of 15.1 MeV from ^{11}B + ^{2}D reaction at 50 MeV was recorded for calibration. Also the time-of-flight technique was used for n-γ discrimination.

3. Data analysis and results

We obtained the isospin mixing probability at excitation energy of about 50 MeV in the following nuclei: ^{32}S, ^{36}Ar, ^{44}Ti, ^{60}Zn.

At first the yield of high-energy γ-rays, from the $N \neq Z$ compound nucleus decay, was fitted by the statistical model calculations with no isospin mixing in order to extract the GDR parameters for $N \neq Z$ nuclei. This yield is assumed not to be dependent on isospin mixing. Then, the extracted parameters were used in the statistical model calculations for $N = Z$ neighbouring nuclei at similar excitation energy. It was based on the observation that the GDR parameters ($E_{\rm GDR}$, $S_{\rm GDR}$, $\Gamma_{\rm GDR}$) are very similar for nuclei very close in mass. Thus, in comparison of the statistical model calculations for $N = Z$ nuclei with the measured γ-ray yield there was only one free

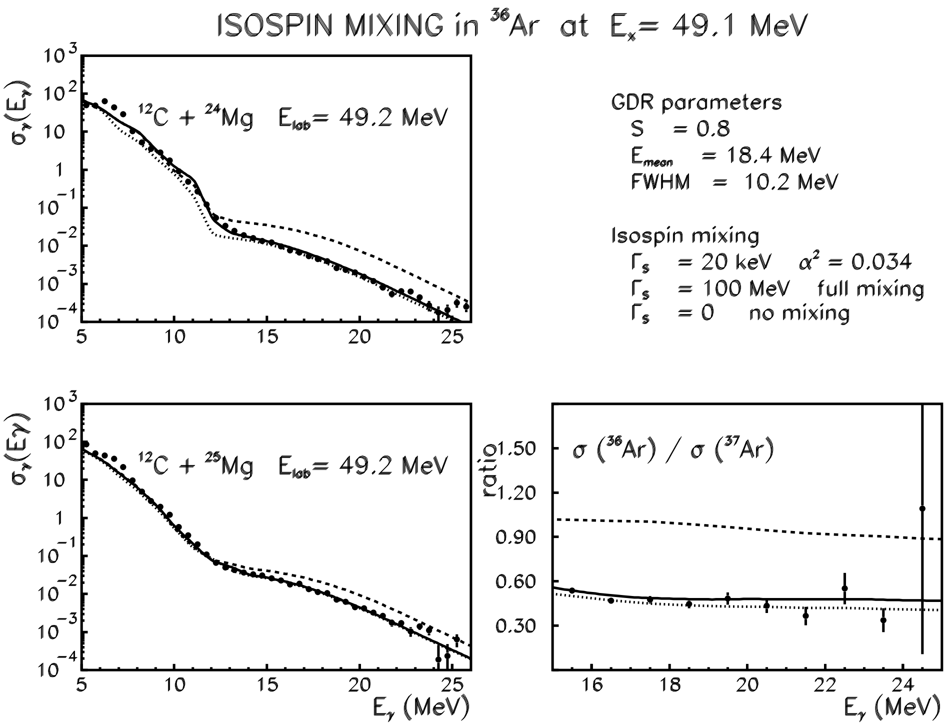

Fig. 1. Spectra of γ-rays emitted during the decay of ^{36}Ar (upper-left) and ^{37}Ar (bottom-left) and the ratios of these spectra (bottom-right). The curves — CASCADE fit with different isospin mixing spreading width: $\Gamma_{>}^{\downarrow} = 0$ — no mixing (dotted curve, the lowest), $\Gamma_{>}^{\downarrow} = 20$ keV (middle, solid curve) and $\Gamma_{>}^{\downarrow} = 100$ MeV — full mixing (upper, dashed curve).

parameter — the Coulomb spreading width $\Gamma^{\downarrow}_{>}$. The best value of $\Gamma^{\downarrow}_{>}$ was extracted and used in the new fitting procedure for the $N \neq Z$ neighbouring nucleus in order to obtain a new set of GDR parameters. If the new values of the GDR parameters were essentially different from those extracted in the first step, the procedure was repeated.

During this process the isospin mixing parameters for four $N = Z$ nuclei were found. It was also noticed that besides the Γ_{GDR} parameter other GDR parameters are only weakly dependent on isospin mixing in nuclei studied.

All calculations were done using a modified version of CASCADE statistical code, where isospin mixing dependence [4, 5], Reisdorf's formula for calculating level density, experimental value of fusion cross-section were included.

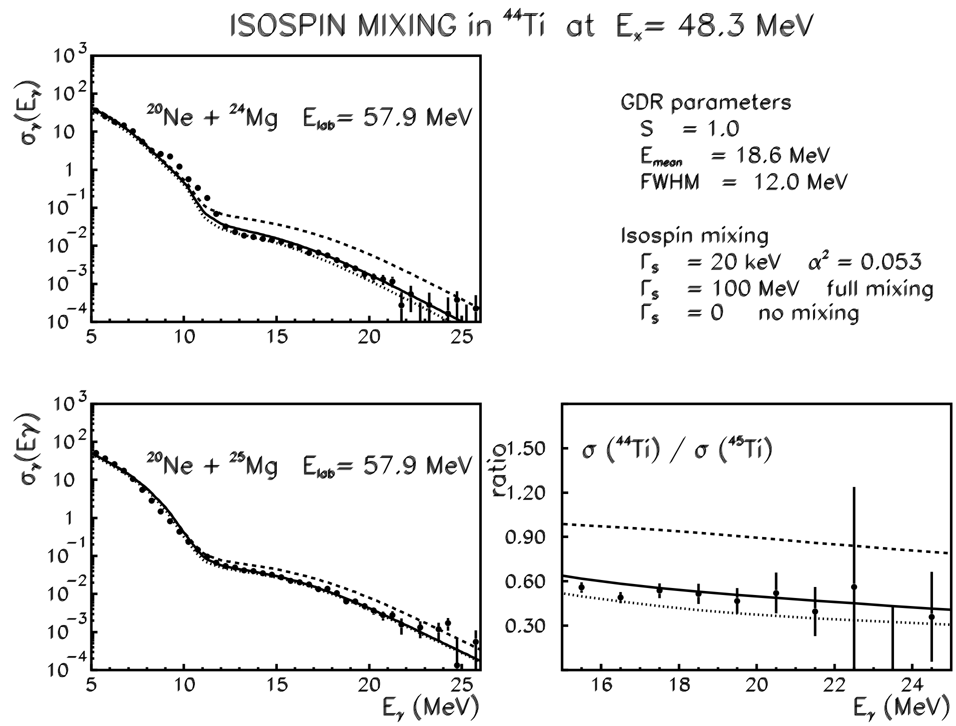

Fig. 2. Spectra of γ-rays emitted during the decay of ^{44}Ti (upper-left) and ^{45}Ti (bottom-left) and the ratios of these spectra (bottom-right). The curves — CASCADE fit with different isospin mixing spreading width: $\Gamma^{\downarrow}_{>} = 0$ — no mixing (dotted curve, the lowest), $\Gamma^{\downarrow}_{>} = 20$ keV (middle, solid curve) and $\Gamma^{\downarrow}_{>} = 100$ MeV — full mixing (upper, dashed curve).

We were able to extract $\Gamma^{\downarrow}_{>}$ at the same value (20 ± 4 keV) for all investigated nuclei. This proves that the Coulomb spreading width does not change much with the nucleus mass.

The isospin mixing probability for every examined nucleus was obtained according to the following formula [4]:

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

Measured high-energy γ-ray spectra from the decay of ^{36}Ar, ^{44}Ti nuclei are presented in Figs. 1 and 2 together with extracted values of the GDR parameters. Results for ^{32}S were published in [7]. We plan to continue in the near future the ^{36}Ar + ^{25}Mg reaction measurement to improve the statistics and verify the value of isospin mixing probability for ^{60}Zn.

4. Conclusions

It was found that the isospin mixing probability in highly excited nuclei at similar excitation energy (temperature) increases with increasing mass number A in the range of A = 32–60 (Fig. 3). This observation is in agreement with the predictions assuming the constant value of the Coulomb spreading width with increasing mass number A at the same excitation energy. It is also in good agreement with theoretical predictions [2, 3].

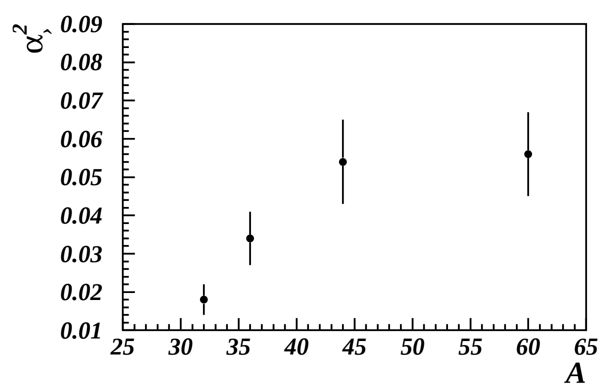

Fig. 3. Isospin mixing dependence on atomic mass.

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