ISOSPIN MIXING AT HIGH TEMPERATURES*

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(Received November 30, 2004)

The isospin mixing in nuclei in the nuclear temperature range from the ground state to the excitation of the compound nucleus to the effective temperature of about 3 MeV is discussed. Theoretical predictions and experimental information from various types of measurements are reviewed. New results for isospin mixing probability measured for ^{32}S and ^{36}Ar at excitation energy around 50 MeV are presented. Possible dependence of the isospin mixing probability on the mass number A in highly excited nuclei is discussed.

PACS numbers: 24.30.Cz, 25.70.–z, 23.20.–g

1. Introduction

In recent years the problem of the mixing of $T \neq T_0$ isospin states with $T = T_0$ states in $N \approx Z$ nuclei, related to the isospin symmetry and its breaking, has been discussed with renewed attention. It is due to progress in experimental techniques, mainly in exploring nuclei near the proton drip line, as heavy as ^{100}Sn. In those nuclei isospin mixing should be enhanced due to stronger Coulomb interaction in heavier nuclei. The understanding of the isospin mixing in nuclear ground states is important because of its impact on the experimental determination of the weak vector coupling constant G_v of nuclear β decay. Thus, it plays a significant role in tests of the Standard Model of electroweak interactions.

It has been predicted long time ago and confirmed by experiments that the isospin mixing probability is small in nuclear ground states and low excited states, as shown in Chapter 2. However, at higher excitation, especially in the region of overlapping resonances, it is often found to be large.

* Presented at the XXXIX Zakopane School of Physics — International Symposium "Atomic Nuclei at Extreme Values of Temperature, Spin and Isospin", Zakopane, Poland, August 31–September 5, 2004.

It has been suggested by Morinaga [1], and Wilkinson [2] nearly 50 years ago, that restoration of the isospin symmetry should occur at even higher excitation. In the last years this fact has been discussed theoretically by Harney, Richter and Weidenmüller [3], Sokolov and Zelevinsky [4], and Sagawa, Bortignon and Colo [5]. They have all shown that at high nuclear temperature strong decrease of the isospin mixing probability should occur, which is equivalent to the restoration of isospin symmetry. It was confirmed experimentally by the studies of the giant dipole resonance (GDR) statistical decay in self-conjugate nuclei [6, 7]. Until now there is still rather limited amount of experimental data concerning the isospin mixing in nuclei at finite temperatures, especially for excitation energy above 20 MeV. Some new results concerning the isospin mixing in highly excited ^{32}S [8] and ^{36}Ar [9] compound nuclei have been obtained in experiments performed by using heavy-ion beams from the Warsaw Cyclotron.

In this talk the isospin mixing probability will be defined and its dependence on the nuclear temperature, in the range from the ground state to the excitation of the compound nucleus to the effective temperature of about 3 MeV will be presented. Theoretical predictions and experimental information from various types of measurements will be reviewed. Finally, possible dependence of the isospin mixing probability on the mass number A in highly excited nuclei will be discussed.

The isospin quantum number was introduced to nuclear physics by Heisenberg [10] in 1932 and applied by Wigner [11] in 1937 to describe the symmetry of the nuclear wave function with respect to the exchange of neutrons with protons. The isospin would be a good quantum number if the Hamiltonian were symmetric under such exchange. This is not the case, and even assuming charge symmetry and charge independence of the nucleon–nucleon interaction, there is the Coulomb interaction $V_{\rm c}$ which is the charge-symmetry violating interaction. This interaction may be represented by isoscalar, isovector and isotensor terms. The scalar operator connects only states of the same isospin. The vector and tensor operators can change the isospin up to one or two units, respectively. Thus, the Coulomb interaction connects states with different isospin. The isovector component is the most important one, and it mixes states with isospin T and $T+1$, called also $T_<$ and $T_>$. There are also other terms in the Hamiltonian violating isospin: the neutron–proton mass difference, magnetic interactions, and possible charge-dependent nuclear forces. It has recently been found [12] that the charge symmetry breaking and charge independence breaking nuclear potentials had to be included in the calculations in order to reproduce the mirror energy differences (MED) and triplet energy differences (TED) of the isobaric multiplet yrast bands. However, the isospin mixing probability due to sources other than the Coulomb interaction, is expected to be at least an order of magnitude smaller. Thus, it is neglected in most of the calculations.

To define the probability of isospin mixing in nuclei the expression in first-order perturbation theory is often used [13, 14]:

$$\alpha^2 = \sum_{T' \neq T} \frac{|\langle T|V_{\rm c}|T'\rangle|^2}{(E_T - E_{T'})^2}\,, \tag{1}$$

which describes the probability that the state with the nominal isospin T has an admixture of states with isospin $T' \neq T$. This formula works well for ground states and low excited states, which are well separated in excitation energy. At high excitation, in the region of high level density, states mix strongly with many nearby levels, so neither such definition of the isospin mixing probability, nor the Coulomb matrix elements between particular states are useful measures of the mixing. Instead, the mixing is described by the spreading width of the state, $\Gamma^{\downarrow}$. This is the width of the energy region over which the state is distributed by mixing with the other states. For small mixing the isospin mixing probability in highly excited nuclei may be approximated by the ratio of the Coulomb spreading width $\Gamma^{\downarrow}$ and the total decay width Γ [3]:

$$\alpha^2 = \frac{\Gamma^{\downarrow}}{\Gamma}\,.$$

2. Isospin mixing probability in the ground states and low excited states of nuclei

The isospin mixing probability in the nuclear ground-state with the nominal isospin T may be calculated by using formula (1), which may be written in the form [14]:

$$\alpha^2_{>} = \left(\frac{Ze^2}{2R^3}\right)^2 \sum_{T+1} \frac{|\langle T,T|\sum_{i=1}^{A} r_i^2 t_z(i)|T+1,T\rangle|^2}{(E_T - E_{T+1})^2}\,, \tag{2}$$

by introducing an assumption that the part of the Coulomb interaction responsible for the isospin mixing is of isovector character and it may be approximated by the potential of uniformly charged sphere with nuclear radius R. The energy difference $(E_T - E_{T+1})$ is the energy separation of the ground state with isospin T from excited states having isospin $T+1$. Large values of the Coulomb matrix elements occur only between states with very similar spatial wave functions and the same spin J^{π}. The most of the strength with isospin $T+1$ and spin J^{π} is concentrated in a single state, the Isovector Giant Monopole Resonance (IVGMR). Its separation from the ground state as well as the separation of the other $T+1$ states is large. Thus, resulting admixtures of the $T+1$ states to the ground state are small. In this case formula (2) provides small value of the $\alpha^2_{>}$ in the ground state.

In a nucleus with $N = Z$ the ground state has $T = 0$ and the isovector excitation carry isospin $T = 1$ only. Most of the theoretical calculations of the isospin mixing probability in the ground state was performed for even–even $N = Z$ nuclei. First calculations were done in 1955 by MacDonald [15] who used the Fermi gas model. During the last ten years several versions of the Hartree–Fock method with Tamm–Dancoff approximations were used, which the isospin mixing probability calculated according to the formula [18]:

$$\alpha_>^2 = \tfrac{1}{2}\langle N = Z|T_-T_+|N = Z\rangle\,.$$

In all those calculations similar results ranging from $\alpha_>^2 = 1\%$ for ^{56}Ni to about 4% for ^{100}Sn were obtained. These values were a factor of 2–3 larger than the earlier estimates made by Bohr and Mottelson [16], who employed a spherical hydrodynamical model and first suggested the existence of an Isovector Giant Monopole Resonance, which would carry most of the monopole strength. Three works will be mentioned here. In calculations by Hamamoto and Sagawa [17], who used spherical Hartree–Fock, a non-smooth Z dependence of $\alpha_>^2$ was obtained, with an increase of $\alpha_>^2$ whenever protons started to occupy next orbital. Dobaczewski and Hamamoto [18] included deformation degree of freedom in their calculations, by introducing pair correlations via BCS approximation, which led to partial occupation of the Hartree–Fock single particle states. A smooth Z dependence of the calculated isospin mixing probability was obtained, but the overall magnitude of $\alpha_>^2$ was very similar to that obtained in [17]. Colo with collaborators [19] presented calculations for a few nuclei with $A \approx 80$ and 100 in spherical Hartree–Fock. But they constructed also a formula for $\alpha_>^2$ based on the energy-weighted sum rule for isovector monopole excitations, in which they used the resonance energy estimated from the hydrodynamical model:

$$\alpha_>^2 = \frac{16.09}{T+1}\frac{NZ^3}{A^{7/3}}\frac{1}{(E_{\rm IVGMR} - E_T + 4V_1(T+1)/A)^3}\,. \tag{3}$$

The energy separation, introduced as in formula (2), was corrected to take into account that protons and neutrons are subject to different average potentials resulting in a proton–neutron exchange. Isospin mixing probabilities estimated according to the formula (3) are very close (within 15–20%) to the results of Hartree–Fock calculations. Furthermore, this formula allows to calculate $\alpha_>^2$ for $N \neq Z$ nuclei in an equally simple manner. It can be seen that the amount of isospin mixing is small in all nuclei in the ground states. It increases with the increase in the mass number A and the atomic number Z, but is small along the line of β stability because of the isospin factor $1/(T+1)$, and reaches maximum for $N = Z$ nuclei.

A possible way of studying the violation of isospin symmetry induced by the Coulomb interaction is the observation of the forbidden transitions. The isospin quantum number provides selection rules for different types of nuclear reactions. Thus, reactions involving absorption and emission of heavy particles, for example reaction (d, α) going from the ground state of $N = Z$ nucleus to the $T = 1$ states of the final $N = Z$ nucleus, are forbidden, on the assumption that isospin should be conserved in the strong interaction. For β-decay and Fermi transitions the $\Delta T = 0$ selection rule applies, when for Gamow–Teller transitions $\Delta T = 0$ or ± 1 is required but transitions from states with $J^\pi = 0^+$ to states with $J^\pi = 0^+$ are forbidden. For E1 transitions in $N = Z$ nuclei transitions between initial and final states with the isospin $T = 0$ and $T_z = 0$ are forbidden. Many experimental results have been obtained about 30 years ago where isospin forbidden Fermi β-decay was observed in nuclei from ^{20}F to ^{228}Ac and all values of extracted isospin mixing probability, reported by Bertsch and Mekjian [13], were below 1%. In case of β-decay useful information is also provided by the deviation of the super-allowed decays from the nominal values of ft. Hagberg *et al.* [20] investigated isospin mixing in ^{38m}K, ^{46}V, ^{50}Mn and ^{54}Co by measuring the branching ratios of non-analogue 0^+ to 0^+ Fermi transitions. Extracted $\alpha^2_>$ was below 0.1%. Even smaller value was measured by Schuurmans *et al.* [21] for the ground state of ^{52}Mn via anisotropic positron emission. It was determined from the isospin forbidden Fermi component in the Gamow–Teller dominated β-decay. Bertsch and Mekjian [13] reviewed also values of the isospin mixing probability for several $N = Z$ nuclei, estimated from the measured strength of forbidden E1 transitions. They were determined from the amount of dipole strength required in the decaying state to account for the observed transition. All values are very small, below 0.3% for nuclei from ^{10}B to ^{36}Ar. Nuclei with $N = Z$ larger than 20 have been the subject of precise contemporary experiments using large γ-arrays. In ^{64}Ge ($N = Z = 32$) the transition deexciting the 5^- level to the 4^+ level with an assigned electric dipole character was observed by Ennis *et al.* [22], and an isospin mixing probability of a few percent was deduced for those states from perturbation theory to get an agreement with the measured data. In a subsequent experiment by Farnea *et al.* [23] the transition strength $B(\mathrm{E1})$ for this transition was also measured and an isospin mixing probability of 2.5%(+1%, −0.7%) was finally assigned. M1 transition rates can also provide information on the isospin mixing. The isoscalar ($\Delta T = 0$) M1 transitions are very strongly suppressed in comparison with the isovector ($\Delta T = 1$) M1 transitions. Recently discovered doublet of 4^+ states with isospin $T = 0$ and $T = 1$ in ^{54}Co decays to 3^+ state with the E2/M1 mixing ratio close to zero for 4^+_1 and 0.12 for 4^+_2. The isospin mixing probability is estimated to be 0.23% (+0.29%, −0.10%) [24] using experimental E2/M1 mixing ratio and M1 and E2 matrix elements calculated within the shell model. Isospin breaking effects can be studied in pairs of mirror nuclei, in which the number of protons and neutrons are interchanged. These effects led to the shifts between the excitation energies of a mirror pair or an isospin triplet. Experimental and theoretical investigation of MED and TED in yrast bands gives an evidence of isospin mixing and the nuclear isospin non-conserving terms in the nuclear interactions. As an example different decay pattern for the $7/2^-$ states in ^{35}Ar–^{35}Cl mirror nuclei was found to be due to isospin mixing [25]. New data for isospin mixing probability extracted by this method should appear soon.

3. Isospin mixing probability at high excitation

At higher excitation, the excited state with isospin T and the states with isospin $T+1$ may decay by statistical emission of particles and γ-rays. The corresponding widths, $\Gamma_<$ for states with isospin $T_< = T$ and $\Gamma_>$ for states with $T_> = T+1$, are the particle decay widths and they increase exponentially with the excitation energy. Thus, a formula for the isospin mixing probability should account for this fact:

$$\alpha_>^2 = \sum_{T_>} \frac{|\langle T_<|V_c|T_>\rangle|^2}{((E_{T_>} + \frac{i}{2}\Gamma_>) - (E_{T_<} + \frac{i}{2}\Gamma_<))^2}\,. \tag{4}$$

At not very high excitation the decay widths are still small and the $\alpha_>^2$ increases with decreasing level spacing. However, at some excitation energy the decay widths become comparable with the level spacing. It is the region of overlapping resonances, and the $\alpha_>^2$ is expected to have a maximum value in this range of excitation energy. At even higher excitation energy the decay widths become very large, much larger than the values of the Coulomb matrix elements and the $\alpha_>^2$ is expected to decrease. It was postulated by Harney, Richter and Weidenmüller [3] that formula (4) should not be used to calculate the isospin mixing probability at so high excitation. It is better to analyze the $\alpha_>^2$ in terms of the spreading width, $\Gamma^\downarrow$, which is much less dependent on excitation energy than the Coulomb matrix elements. Experimental average Coulomb matrix elements for states of excitation energies E_x from 15 to 40 MeV vary by six orders of magnitude. Plotting these values as a function of $\sqrt{AE_x}$ one observes exponential dependence (see Fig. 14 in [3]). This suggests that the exponentially increasing level density is responsible for the decrease of the average Coulomb matrix element between individual states with increasing E_x. The Coulomb spreading width:

$$\Gamma_>^\downarrow = 2\pi\overline{|\langle T_>|V_\mathrm{c}|T_<\rangle|^2}\rho(T_<)$$

depends on both the average matrix element and the level density ρ. Thus, their influences cancel, and as it is shown in Ref. [3], all known experimental

Coulomb spreading widths vary by less than 2 orders of magnitude. Harney *et al.* [3] have given a qualitative argument on the basis of sum rules to support experimental suggestion that the Coulomb spreading width $\Gamma^{\downarrow}$ should not change much with excitation energy or mass of the nucleus. The formula connecting isospin mixing probability in $N = Z$ nuclei with the spreading width was derived within the framework of the S-matrix formalism [3, 7]:

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

The compound nuclei decay widths $\Gamma_{>}$ and $\Gamma_{<}$ increase rapidly with excitation energy and at excitation of 40–60 MeV are much larger than the Coulomb spreading width that has been measured at lower excitation energy [3]. Thus, Harney, Richter and Weidenmüller [3] have shown that, under the assumption that the Coulomb spreading width does not change with excitation energy, $\alpha_{>}^{2}$ should be small at high excitation and decrease with excitation energy increasing. Similar relation was derived by Sagawa, Bortignon and Colo [5] who used a microscopic model based on the Feshbach projection method. Their formula gives an explicit relation between the spreading width of the Isobaric Analog State $\Gamma_{\rm IAS}^{\downarrow}$ and the isospin mixing probability:

$$\alpha_{>}^{2} = \frac{1}{T_{>}} \frac{\Gamma_{\rm IAS}^{\downarrow}(E_x)}{\Gamma_c(E_x) + \Gamma_{\rm M}(E_x)} \,. \qquad (5)$$

It applies to all nuclei, also with $N \neq Z$, for which the isospin factor $1/T_{>}$ is necessary. The compound nuclei decay width Γ_c present in the denominator of equation (5) is expected to rise significantly with excitation energy, when the total width of the IVGMR $\Gamma_{\rm M}$ is not. The authors presented $\alpha_{>}^{2}$ as a function of nuclear temperature t. The results of the calculations are shown for ^{208}Pb. At higher excitation, corresponding to $t > 1$ MeV, the $\alpha_{>}^{2}$ decreases and at $t =$ 3 MeV is reduced by a factor of about 4.

Experimental evidence for isospin mixing at excitation around 20 MeV, may be obtained from studies of evaporation spectra from $(\alpha, \alpha'), (p, p')$, $(p, \alpha'), (\alpha, p')$ reactions proceeding through the same compound nucleus populated at the same excitation energy [3, 26, 27]. If the isospin is completely mixed, then the experimental ratio

$$R = \frac{\sigma(\alpha, \alpha')\sigma(p, p')}{\sigma(\alpha, p')\sigma(p, \alpha')}$$

of the measured cross sections is approximately unity, because of Bohr's independence hypothesis. When isospin is conserved, R is larger than 1, since the (p, p') reaction can proceed through $T_{<}$ and $T_{>}$ levels, while the other reactions are restricted to the levels with isospin $T_<$. Extracted values of $\alpha^2_>$ for ^{64}Zn and ^{69}Ga in the excitation energy range of 17–24 MeV changed from 50 to 30% [26, 27]. Isospin mixing at similar excitation may be also obtained from comparison of (α, γ) cross sections for two reactions, one with a self-conjugate target nucleus, the other with a neighboring target nucleus but with $T \neq 0$. In the first reaction, the E1 γ-decays are forbidden; in the second — they are allowed. Comparison of γ yields for these reactions allows to extract $\alpha^2_>$. Excitation energy range studied in this method corresponds to the excitation of GDR built on the ground state. Extracted $\alpha^2_>$ for ^{28}Si at excitation energy around 19 MeV was 25% [28].

Evidence of an isospin mixing at excitation energy higher than 20 MeV may be studied in heavy-ion capture reactions which lead to the statistical emission of high-energy γ-rays from the GDR decay. Let us assume that the isospin is conserved. When $N = Z$ compound nuclei are formed by entrance channel with the isospin $T = 0$, then only states with $T = 0$ can be populated. The E1 decays from $T = 0$ to $T = 0$ states are isospin forbidden due to isovector nature of the electric dipole radiation. The transitions from $T = 0$ to $T = 1$ states are allowed but there are not many $T = 1$ final states available to be populated by the GDR decays. Thus, the yield of high-energy γ-rays in the statistical decay of self-conjugate nuclei, populated by entrance channels with the isospin $T = 0$, is due to GDR γ-decays of the compound nucleus populating $T = 1$ final states, and γ-decays in daughter nuclei formed by particle emission. This yield is suppressed by a factor of about 3 in comparison with the yield from the decay of neighboring compound nuclei with $N \neq Z$, at similar excitation energy, where transitions between states with the same isospin are allowed. When, however, the isospin is not conserved and an isospin mixing occurs, the yield of high-energy γ-rays in γ-decay of $N = Z$ compound nuclei is larger. This effect was first used to determine the isospin mixing probability in ^{28}Si and ^{24}Mg [6]. Later on the method was improved and used to study the dependence of the isospin mixing probability on the initial excitation energy of the compound nuclei ^{26}Al and ^{28}Si [7]. In a similar way we have extracted isospin mixing probability in ^{32}S nuclei by measuring ^{20}Ne + ^{12}C and ^{19}F + ^{12}C reactions with the Warsaw Cyclotron beams [8]. We measured inclusive γ-ray cross sections for ^{32}S with $T = 0$ and for neighboring ^{31}P compound nuclei with $T = 1/2$ formed at similar excitation energies. At first, we analyzed the γ-ray spectra from decay of ^{31}P nuclei, by choosing appropriate values of the statistical model parameters and GDR parameters, which reproduced well the spectra. Calculations included the isospin, the experimental value of fusion cross-section, level densities given by the Reisdorf's parameterization, and a spin-dependent moment of inertia in agreement with the RLDM. The GDR parameters have been treated as free parameters in the fitting. In the $N \neq Z$ nuclei the E1 decays to all final states are allowed, and the

γ-ray yield depends much less on the isospin mixing. Thus the GDR parameters are extracted with a high level of confidence. We have then used the same GDR parameters and statistical model parameters in statistical model CASCADE calculations for ^{32}S nuclei and tried to obtain the isospin mixing probability. We used the Coulomb spreading width $\Gamma_{>}^{\downarrow}$ as a parameter. Our method based on the GDR statistical decay is sensitive to the admixture of the states with isospin $T_{<}$ to the states with isospin $T_{>}$, thus we should in fact use $\Gamma_{<}^{\downarrow}$ and $\alpha_{<}^{2}$ to characterize the isospin mixing. But we have choosen $\Gamma_{>}^{\downarrow}$ and $\alpha_{>}^{2}$ used more often in other works for easy comparison with literature.

In order to increase the sensitivity to the isospin mixing we have analyzed the ratios of γ-ray cross sections for the reactions forming $N = Z$ and $N \neq Z$ neighboring nuclei, for the measured and calculated yields. In this way small errors in the statistical calculations canceled and the dependence on the GDR parameters was removed. Our results are consistent with small isospin mixing, $\Gamma_{>}^{\downarrow} = 20 \pm 25$ keV, $\alpha_{>}^{2} = 0.021 \pm 0.024$, at 58.3 MeV initial excitation energy, in agreement with Ref. [3]. This year some preliminary results for isospin mixing probability in ^{36}Ar have been obtained by measuring ^{12}C + ^{24}Mg reaction with the Warsaw Cyclotron beam [9]. In our method, data from the decay of ^{39}K formed in ^{12}C+^{27}Al measured earlier [30], were used as a high-energy γ-ray spectrum for $N \neq Z$ neighboring nuclei. Values of the Coulomb spreading width and the isospin mixing probability $\Gamma_{>}^{\downarrow} = 90$ keV $\pm$ 40 keV, and $\alpha_{>}^{2} = 0.12 \pm .05$, for ^{36}Ar at initial excitation energy of 49.1 MeV were extracted. Results for heavier nuclei ^{60}Zn have been obtained in Seattle and they show similar trend as a function of initial excitation energy of the compound nucleus [29].

In order to qualitatively compare the temperature dependence of the isospin mixing probability found for nuclei with mass $A = 26$–60 [6–9, 29] with the theoretical predictions [3, 5], the measured values are presented in Fig. 1 (left) as a function of nuclear temperature. The temperature was calculated here as the effective temperature t of the formed compound nucleus which is the most sensitive in the decaying cascade to the isospin mixing:

$$t = \sqrt{(E_x - \Delta_{\rm p} - E_{\rm rot})/a}\,,$$

where the E_x was the initial excitation energy of the compound nucleus. The rotational energy $E_{\rm rot}$ was estimated for the average spin of the compound nucleus. The pairing energy $\Delta_{\rm p}$ and the level density parameter a were calculated within the level density Reisdorf's parametrization. It is seen that the $\alpha_{>}^{2}$ decreases substantially when t increases from 1.6 MeV to 3 MeV.

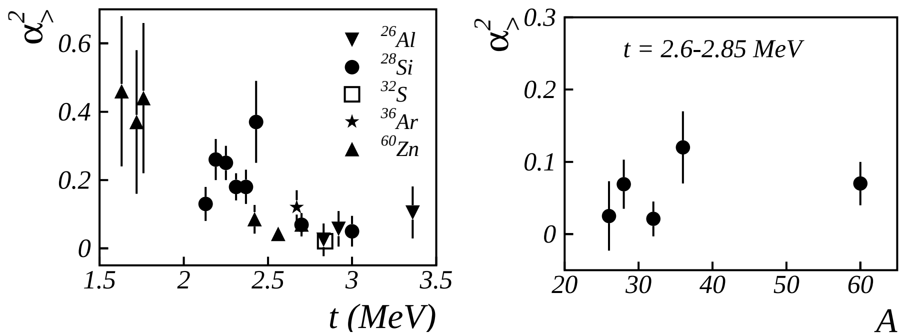

Fig. 1. Left: The isospin mixing probability in nuclei with A= 26–60 as a function of nuclear temperature t; right: The isospin mixing probability in nuclei as a function of nuclear mass. The data of $\alpha^2_<$ for ^{26}Al and^{28}Si were taken from Ref. [7], for ^{32}S from [8], for ^{36}Ar from [9] and transformed to $\alpha^2_>$, data for ^{60}Zn were taken from [29].

In nuclei in the ground state, the dependence of the isospin mixing on the mass number A and the atomic number Z was predicted [19]. It may be expected that it should occur also in highly excited nuclei. From the measured values of the isospin mixing probability [6–9, 29], those at similar temperature were chosen and presented in Fig. 1 (right). The value for ^{60}Zn nuclei is of a crucial importance here. We plan to continue our study of isospin mixing for ^{44}Ti and ^{60}Zn nuclei at effective temperature around 2.7 MeV.

4. Conclusion

Thus, measured isospin mixing probability confirms restoration of isospin symmetry in highly excited nuclei, pointed out theoretically by Morinaga [1] and Wilkinson [2] already 50 years ago, and derived from different approaches by Harney, Richter and Weidenmüller [3] and by Sagawa, Bortignon and Colo [5]. It was confirmed experimentally by Behr *et al.* [7] for ^{28}Si nuclei, where the decrease of the isospin mixing probability was measured for increasing initial excitation energy of the compound nuclei. The explanation for this effect is the rapid increase of the compound nucleus decay width with the temperature, and the near constancy of the Coulomb spreading width. As it was mentioned by the authors of Refs. [3] and [5], the isospin symmetry is partially or totally restored, if the compound nucleus decays on a time scale which is shorter than the time needed for a well-defined isospin state to mix with states with different isospin. The dependence of the isospin mixing probability on nuclear mass in highly excited nuclei is not clear yet. We plan to continue our study for ^{44}Ti and ^{60}Zn nuclei in a near future to try to answer this question.

This work was partly supported by the Polish State Committee for Scientific Research (KBN) Grant No. 2 P03B 030 22.

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