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Gamow-Teller Decay of ^{100}In

A. Blazhev[1,2], **C. Plettner**[2], **L. Batist**[2], **J. Döring**[2], **H. Grawe**[2], **M. Górska**[2], **M. Gierlik**[3], **Z. Janas**[3], **M. Karny**[3], **R. Kirchner**[2], **C. Mazzocchi**[2,4], **I. Mukha**[2], **E. Roeckl**[2], **R. Schwengner**[5]

[1]University of Sofia, BG-1164 Sofia, Bulgaria

[2]GSI, D-64291 Darmstadt, Germany

[3]IEP University of Warsaw, PL-00681 Warsaw, Poland

[4]Universitá degli Studi di Milano, I-20133 Milano, Italy

[5]FZ Rossendorf, D-01314 Dresden, Germany

Abstract.

The β^+/EC-decay of ^{100}In, the one proton-hole and one neutron-particle neighbour nucleus to the doubly-magic ^{100}Sn, was investigated at the GSI ISOL facility by using a Germanium detector array for high-resolution spectroscopy and a highly-efficient NaI total-absorption spectrometer (TAS) to measure the Gamow-Teller (GT) strength and distribution. The beta-decay scheme was studied for the first time. Large-scale shell-model calculations using a realistic interaction are used to assign configurations to low-lying states in ^{100}In and ^{100}Cd. The experimental GT beta-decay strength distributions as measured in TAS are compared to shell-model predictions. The hindrance factor for the total GT strength amounts to h=4.1(9). This value agrees well with a value extrapolated for the GT resonance in ^{100}Sn from previously measured values in neighbouring nuclei.

1 Introduction

Nuclear structure physics in N$\sim$Z nuclei is intimately related to the effects caused by the vicinity of the proton drip-line and by the occupation of identical orbits for protons and neutrons. This is of great importance for understanding the astrophysical rp-process. The nuclear β decay is specifically suited to study isospin mixing and drip-line effects in Fermi transitions, while the Gamow-Teller

(GT) transition probes core excitations around doubly magic nuclei and the gross strength of the proton-neutron residual interaction.

In the recent years, decays of N$\sim$Z nuclei have in particular been studied at ISOLDE/CERN, GANIL and GSI. Here we present preliminary results from the theoretical shell-model interpretation of the experimental work, concerning the GT β-decay studies in the region of the doubly magic ^{100}Sn, namely the study of the β-decay of ^{100}In. It should be mentioned that the β-decay of nuclei below ^{100}Sn due to the large decay energy window offers the chance to observe the entire GT resonance.

2 Experimental Techniques

The experiments were performed at the GSI ISOL exploiting a heavy-ion induced fusion-evaporation reaction of a 6.2 A·MeV ^{58}Ni beam on a ^{50}Cr target.

The *high-resolution* spectroscopy of β-delayed γ-rays emitted from the mass-separated sources was accomplished by using germanium (Ge) detectors, including those of the Euroball-Cluster and Clover type. Beta-delayed γ-rays were measured in coincidence with positrons recorded in a plastic-scintillation detector.

As a *low-resolution* but high-efficiency alternative to the γ-ray detectors described above, a total-absorption spectrometer (TAS) was used. The TAS [1] consists of a large NaI crystal surrounding the radioactive source, two small Si detectors above and below the source, and one Ge detector placed above the upper Si detector. By demanding coincidence with signals from the Si detectors, the β^+-decay component for the nucleus of interest is selected, whereas a coincidence condition with characteristic X-rays recorded by the Ge detector can be used to select the EC mode. In this way the *complete* distribution of the β strength can be determined for neutron-deficient isotopes and the Q_{EC} value can be deduced from the ratio between β^+ and EC intensities. Beta-delayed protons were measured by the Si E-detector facing the source.

3 Results and Discussion

Details of the experimental results will be presented in a forthcoming paper [2]. To gain insight into the microscopic structure of states in ^{100}Cd and ^{100}In, and to study the GT resonance in ^{100}In $\rightarrow$ ^{100}Cd decay, shell-model calculations were performed using the code OXBASH [3]. The model space consists of the active proton orbitals $2p_{1/2}$, $1g_{9/2}$ and of the active neutron orbitals $1g_{7/2}$, $2d_{5/2}$, $2d_{3/2}$, $3s_{1/2}$ and $1h_{11/2}$. The single-particle energies relative to a ^{88}Sr core were chosen to reproduce the extrapolated values for a ^{100}Sn core [4].

The effective interaction was derived by employing a perturbative many-body scheme starting from the free nucleon-nucleon interaction, according to the

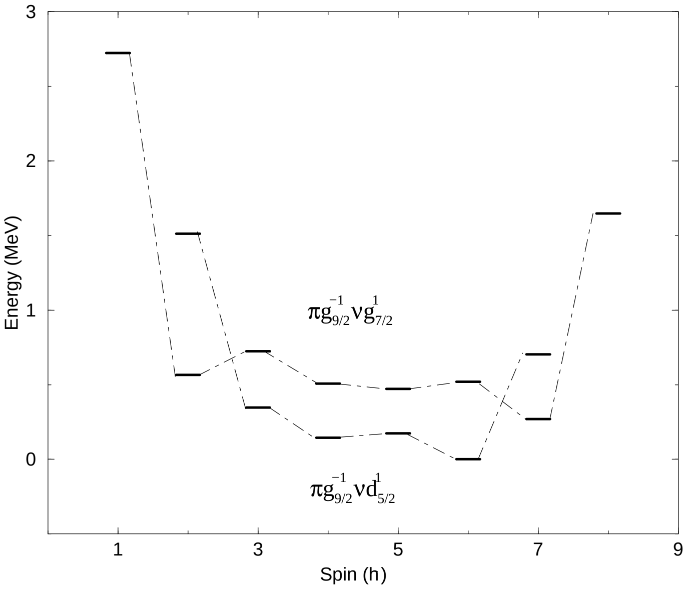

Figure 1. Calculated level energies of the $\pi g^{-1}_{9/2}\nu g_{7/2}$ and $\pi g^{-1}_{9/2}\nu d_{5/2}$ multiplets of ^{100}In. States belonging to the same multiplet are connected to guide the eye.

prescription outlined in Ref. [5]. For calculating the GT-strength distributions the free GT operator was used.

3.1 ^{100}In Ground State

The experimental data do not permit us to draw any firm conclusion with respect to the ground-state spin of the ^{100}In. The shell-model calculations were used to make predictions concerning the $\pi g^{-1}_{9/2}\nu g_{7/2}$ and $\pi g^{-1}_{9/2}\nu d_{5/2}$ multiplet energies in ^{100}In. The calculations shown in Figure 1 favour a ground-state spin of 6 with a $\pi g^{-1}_{9/2}\nu d_{5/2}$ configuration. The 7^+ originating from $\pi g^{-1}_{9/2}\nu g_{7/2}$ is 250 keV above the 6^+. The ground state of ^{102}In, being tentatively assigned a spin of 6, originates from the $\pi g^{-1}_{9/2}\nu d_{5/2}$ multiplet [6]. Based on the experimental observations the shell model reproduces the correct ground-state spin values for heavier indium isotopes $J^\pi = 6^+$, as predicted for ^{100}In (see Section 3.3 for further discussion).

3.2 ^{100}Cd Low-Lying States

In this section the shell-model results shown in Figure 2 are discussed. The first excited state $J^\pi = 2^+$ is very close to the experimental value. It has a mixed configuration, where the valence neutrons occupy mainly the $2d_{5/2}$ orbital (47%),

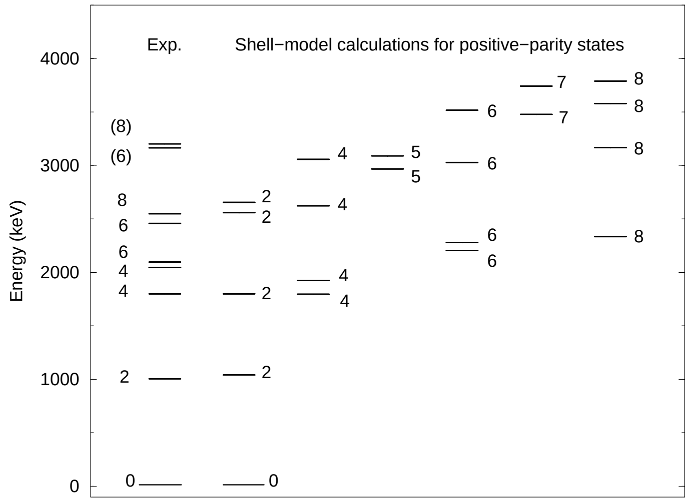

Figure 2. Comparison of experimental ^{100}Cd level energies with shell-model predictions. In the first column the experimental energy levels are presented. The other columns comprise yrast and yrare groups of theoretical states ordered according to their spin and energy.

while about 20% amplitude comes from the $1g_{7/2}$ orbital. For all the shell-model states presented in Figure 2, the proton contribution to the wave function is largely dominated by two holes in the $1g_{9/2}$ and two particles in the $2p_{1/2}$ orbitals, the other configurations with different occupancies playing no significant role. The 4_1^+ state, correctly predicted in energy, has the same dominant structure as the 2_1^+ state, which remains valid for the 6_1^+ state as well. The 4_2^+ wave function is more fragmented since the dominant configuration is identical with that of 4_1^+ state, but significant contributions originate from neutrons either in $d^1_{5/2}d^1_{3/2}$ or in $g^1_{7/2}d^1_{5/2}$ coupling. This is the lowest state where the pair of valence neutrons is broken and the seniority differs from 0; the next state of this character is 6_2^+ . The largely different wave functions of the 4_1^+ and 4_2^+ states result in a lower mixing between the corresponding levels which leads to two close-lying 4^+ states, which is in agreement with the experiment. A more dramatic effect is observed for the first two 6^+ states, since their wave functions have no major overlap, and thus their energy spacing is calculated to be 78 keV only. In the experiment, this spacing is much larger, which may indicate that the wave functions have a slightly different structure than predicted. The calculated 8_1^+ state, predominantly of $\pi g^{-2}_{9/2}$ character, lies somewhat lower than observed in the experiment. The configuration assignments agree also with previous shell-model calculations for ^{100}Cd [7].

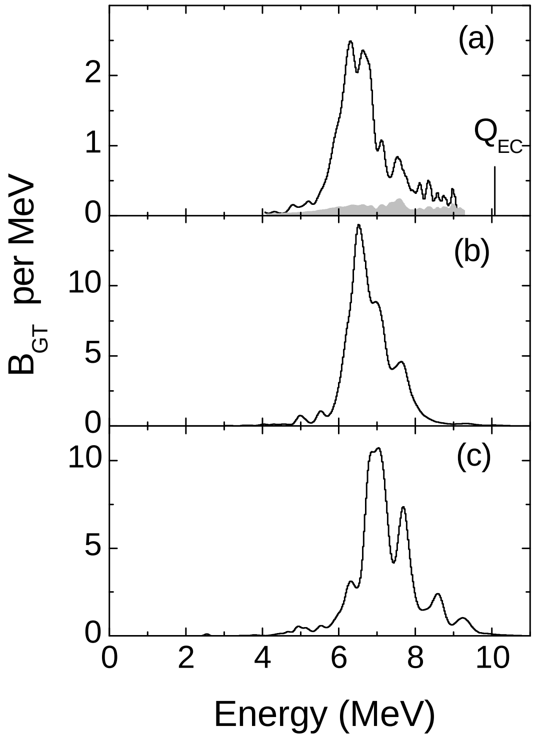

Figure 3. Total experimental B_{GT} distribution (a) compared to theoretical distributions calculated in the shell model for parent nucleus ground state spin assumptions of 6^+ (b) and 7^+ (c). The experimental Q_{EC} value is indicated by an arrow. The experimental uncertainties are indicated as a shadowed area in panel (a). The structure at high energies in the spectrum (a) corresponds to β-delayed proton contribution.

3.3 GT Distribution

The experimental distribution of the GT strength as a function of the ^{100}Cd excitation energy, deduced from the TAS data, is plotted in Figure 3(a). It shows a pronounced resonance at an energy around 6.4 MeV with a width of about 1 MeV. It is compared to shell-model predictions in Figure 3(b,c), assuming 6^+(Figure 3(b)) or 7^+(Figure 3(c)) for the ground state of ^{100}In. The shape of this GT resonance agrees with that obtained by the shell-model calculation Figure 3(b) where 6^+ was assumed for the ^{100}In ground state. The position and the width of the resonance are reproduced very well. The small upward shift in position can be attributed to the neglect of excitations of the ^{100}Sn core. It has been pointed out earlier [8] that a small renormalization of the proton-neutron interaction strength can account for this shift. Total GT strengths of 15.9 and 14.4 are calculated for the cases of 6^+ and 7^+ being the ground state of ^{100}In, whereas 3.9(9) was determined experimentally in the present work. This translates into hindrance factors of h(6^+) = 4.1(9), and h(7^+) = 3.7(9), correspondingly. As both systematics (see Section 3.1) and the comparison to shell model seem to favour $J^\pi = 6^+$ for the parent state, the hindrance h(6^+) should be compared to the experimental values of 3.8(7) for ^{98}Cd [9] and to that of 4.3(6) measured for ^{97}Ag [8]. The theoretical hindrance factor of ^{100}Sn is 3.0 [8]. Thus, within the large experimental uncertainties, the ^{100}In β decay exhausts the predicted strength of the GT resonance predicted for ^{100}Sn.

4 Summary

By using heavy-ion induced fusion-evaporation reactions at the ISOL facility of GSI, new and interesting data have been obtained for the β decay of ^{100}In, the one proton-hole and one neutron-particle neighbour nucleus to the doubly-magic ^{100}Sn. The performed shell-model calculations yield in a good description of the experimental data. The comparison of theory and experiment for the GT distribution seems to favour $J^\pi = 6^+$ for the ^{100}In parent state, while a 7^+ assignment cannot be ruled out on grounds of pure experimental evidence. The hindrance factor for the total GT strength, that has to be applied with reference to the shell-model value, is qualitatively understood (see [8, 9] for details) and in the case of ^{100}In GT decay amounts to h=4.1(9).

References

[1] M. Karny *et al.*, (1997) *Nucl. Instr. and Meth. in Phys. Res.* **B126** 411.

[2] C. Plettner *et al.*, *Phys. Rev.* **C** in print.

[3] B.A. Brown, A. Etchegoyen, and W.D.M. Rae, (1988) T*he computer code OXBASH, MSU-NSCL report* **524**.

[4] H. Grawe and M. Lewitowicz, (2001) *Nucl. Phys.* **A693** 116.

[5] M. Hjorth-Jensen *et al.*, (1995) *Phys. Rep.* **B261** 261 and priv. comm.

[6] M. Lipoglavšek *et al.*, (2002) *Phys. Rev.* **C65** 021302(R).

[7] D. Alber *et al.*, (1992) *Z. Phys.* **A344** 1.

[8] Z. Hu *et al.*, (1999) *Phys. Rev.* **C60** 024315.

[9] B.A. Brown and K. Rykaczewski, (1994) *Phys. Rev.* **C50** 2270.