Gamow Teller decay of deformed neutron-rich nuclei*

A. Jokinen, J. Äystö, P.P. Jauho, M. Leino†, J.M. Parmonen and H. Penttilä
Department of Physics, University of Jyväskylä, SF-40351 Jyväskylä, Finland

K. Eskola
Department of Physics, University of Helsinki, SF-00170 Helsinki, Finland

Z. Janas and J. Zylicz
Department of Experimental Physics, Warsaw University, PL-00-681 Warsaw, Poland

We have studied Gamow Teller (GT) strength and its distribution as a function of deformation in neutron-rich nuclei between strongly deformed Zr and nearly spherical Pd isotopes. The mass region studied is one of the few areas on the neutron-rich side of the nuclide chart where fast beta transitions occur between the spin partner shell model orbits $\nu g_{7/2}$ and $\pi g_{9/2}$. To first order in spherical approximation only one GT-transition, $|0^+\rangle \rightarrow |\nu g_{7/2}^{-1} \pi g_{9/2}; 1^+\rangle$ is possible. Under nuclear deformation spherical states are split to Nilsson states labeled by the asymptotic quantum numbers $K^\pi[Nn_3\Lambda]$. The spin-flip transitions obeying the additional asymptotic quantum number selection rules: $\Delta K=1$, $\Delta N=0$, $\Delta n_3=0$ and $\Delta\Lambda=0$ are called unhindered (au) and can be identified by their low log ft-values, log ft≤5 [1].

As a first step in our experimental program we have chosen to study the decay of even-even nuclei, because they provide a unique spin and parity assignment for the parent state. A reduced GT-strength is connected with the experimental observables via the expression B(GT)=3862/ft, where f is the phase space factor and t is the partial half-life. The constant in expression has been calculated using the free nucleon value of the ratio of the axial to vector coupling constants $|g_A/g_V|=1.263$ [2]. The determination of B(GT) involves the measurement of the half-life and the decay energy as well as the determination of the level scheme of the daughter nucleus. The studied isotopes were produced in a symmetric fission of ^{238}U. All experiments were performed using the MC-20 cyclotron and the IGISOL on-line mass separator facility located at the Department of Physics of the University of Jyväskylä [3].

The first series of experiments concentrated on the study of the decays of the even-even ^{114,116,118}Pd isotopes [4]. After that we have reinvestigated the decay of ^{118}Pd and also studied the beta decay of a new nuclide ^{120}Pd [5]. In each case, detailed level scheme was constructed and two to four 1^+ states were observed to be fed by the allowed beta transitions. The beta decaying Pd isotopes and their daughter nuclides are relatively weakly deformed [6], with different shapes competing at low excitation energies, even for the 1^+ states. This complicates the analysis of the beta strength. Thus, it was of

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† On leave from the Department of Physics, University of Helsinki.

interest to extend these studies to Ru isotopes, which are expected to have more pronounced ground state deformation. Prior to our studies only the half-life and the 112 keV γ-ray were known in the decay of ^{110}Ru. No reliable experimental data were available or known for ^{112}Ru and ^{114}Ru. The decay schemes of ^{110}Ru and ^{112}Ru have been presented in ref. [7] and the decay of ^{114}Ru has been discussed in ref. [8]. The data for the beta decay of ^{114,116,118,120}Pd and ^{108,110,112,114}Ru are summarized in Table below.

Table. Summary of decay data for the even-even $_{46}$Pd and $_{44}$Ru isotopes.

Nuclide	$T_{1/2}$ [s]	Q_β [MeV]	log ft	B(GT)	$100B_{exp.}/B_{th.}$ [(a)]	Ref.
^{114}Pd	145(9)	1.45(10)	4.14	0.28	7.5	[4]
^{116}Pd	10.8(2)	2.62(10)	3.93	0.45	14.2	[4]
^{118}Pd	1.9(1)	4.1(2)	4.0	0.49	17.0	[5]
^{120}Pd	0.5(1)	5.5	<3.96	0.42	15.9	[5]
^{108}Ru	273(3)	1.35(6)	4.17	0.26	-	[8]
^{110}Ru	11.6(6)	2.81(5)	4.18	0.26	4.9	[7]
^{112}Ru	1.75(7)	4.52(8)	4.23	0.23	5.1	[7]
^{114}Ru	0.57(5)	6.12(20)	<4.35	0.17	4.4	[8]

(a) QRPA-model of Suhonen et al. [9]

The total experimental strength was first compared to the strength calculated with the spherical QRPA model [9]. This model includes several single particle orbitals, which can act together lowering the amplitude of the leading term, $(\nu g_{7/2}^{-1}\pi g_{9/2})$. However, even in the less deformed $^{114\text{-}120}$Pd isotopes, this was not enough to bring the theoretical values down to the level of the experimental GT-strength, which was of the order of 10-20 % of the predicted one. This can partly due to a nuclear deformation, which was not included in a calculation. In the case of the more deformed $^{108\text{-}114}$Ru isotopes, the experimental GT-strength was even lower compared to the calculated strength, as shown in Table.

To test a possible role of the deformation we have applied the macroscopic-microscopic model of [10] to calculate the 1^+ distribution of the odd-odd Ag and Rh isotopes. According to calculations, the main part of the GT-strength is connected with transitions originating from the $(\nu g_{7/2}^{-1}\pi g_{9/2})$ parentage. The observed splitting of the 1^+ states could be approximately reproduced in the calculations. These calculations suggest an oblate deformation for the even-even Pd and Ru isotopes with a quadrupole deformation of the order of β_2= -0.2. However, the calculated potential energy surface is relatively flat in the case of Pd isotopes.

Prior to our studies, the decay energies of Ru isotopes were known up to ^{109}Ru [11]. We have determined the decay energies of ^{110,112,114}Ru isotopes first time and this data can be used to test the mass predictions of the neutron-rich Ru isotopes. All mass predictions of the compilation of [12] seems to underestimate the decay enegies of Ru isotopes. On the contrary, macroscopic-microscopic model of [10] can reproduce the decay energies of the studied Ru isotopes, when the liquid drop part is taken according to ref. [13]. The similar result was shown in the case of Pd-isotopes [4].

The comparison of the experimental half-lives of the even Ru isotopes with the recent half-life predictions based on the deformed QRPA model of Möller and Randrup [14] supports also the oblate deformation for these isotopes [15].

Despite the vast amount of new experimental data, the puzzle of the oblate vs. prolate deformation when going from Pd to Mo isotopes has not yet been solved. Experiments were extended to more deformed nuclei, like ^{106,108,110}Mo and ^{102,104}Zr isotopes. The analysis of these experiments is in progress. The construction of the new heavy ion cyclotron at Jyväskylä and efforts put to improve the efficiency of the IGISOL-device allows the continuation of these studies even further from the line of the beta stability.

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