EVALUATION OF β-DECAY FEEDING INTENSITY IN ^{182}Au EC/β^+ DECAY*

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The EC/β^+ decay of ^{182}Au was studied at the ISOLDE facility at CERN. Method of prompt γ–γ coincidences was used to build the level scheme of its daughter isotope, ^{182}Pt. The intensity of observed transitions was determined and used to calculate the amount of β-decay feeding into excited levels in ^{182}Pt. These values are compared with β-decay feeding intensity values from the latest measurement of ^{182}Au β decay.

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1. Introduction

Nuclei in the neutron-deficient lead region manifest shape coexistence [1] to a large extent. This phenomenon occurs when two or more distinct types of deformation coexist at low excitation energy within the same nucleus. Shape coexistence is well established in the even–even lead and mercury isotopes, where prolate intruder states can be observed alongside the weakly oblate ground states of these nuclei [1–3]. These intruder states can be interpreted as arising from the excitation of proton pairs across the $Z = 82$ closed shell. A similar situation is also present in even-mass platinum nuclei. However, a configuration change occurs around the mid-shell $N = 104$ in $^{178-186}$Pt, and the prolate intruder state becomes the ground state of these isotopes [4, 5].

An effective way to study exotic isotopes is the spectroscopy of γ rays following β decay into excited states of these nuclei. This method allows for the investigation of the properties of populated states, including shape coexistence, as was done for example for ^{180}Hg [6].

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The EC (electron capture)/β^+ decay of ^{182}Au has been already investigated in the past decades [7–9]. In these studies, low-spin excited states in ^{182}Pt were identified up to the excitation energy of ~ 1.9 MeV. The conversion coefficients were evaluated alongside the γ–γ angular correlations resulting in the determination of spin and parity values I^π for several non-yrast excited states.

In this paper, we introduce our investigation of excited states in ^{182}Pt via EC/β^+ decay of ^{182}Au, which was measured during the IS665 experiment [10] at the ISOLDE Decay Station (IDS) [11], and we present partial preliminary results. An order of magnitude higher statistics of γ-ray coincidence data in comparison to previous studies has allowed for extending the currently known level scheme of ^{182}Pt. Full final analysis and discussions will be published elsewhere [12].

2. Experiment

The experiment was performed at the ISOLDE-CERN facility [13, 14]. Nuclei of ^{182}Au were produced in spallation of a 50 g/cm^2-thick UC$_x$ target induced by a 1.4-GeV proton beam provided by the Proton Synchrotron Booster. The beam consisted of 2.4-μs-long pulses with a repetition time of 1.2 s, with an average intensity of up to 2 μA. Produced nuclei effused out of the target heated to $\approx 2000^\circ$C through the transfer line into the hot cavity of the Resonance Ionization Laser Ion Source (RILIS) [15]. Gold atoms were selectively ionised inside this cavity using a three-step resonance ionisation scheme [16]. Ions were extracted by the 30-kV electrostatic potential and separated according to their mass-to-charge ratio by the General Purpose Separator.

The high-purity ^{182}Au beam was implanted on a movable aluminized mylar tape inside the vacuum chamber of the IDS. This tape was automatically moved every ~ 30 s to remove long-lived daughter activities. Four HPGe Clover detectors, used for X- and γ-ray detection, were placed outside the vacuum chamber. Both the energy calibration and the absolute detection efficiency calibration of these detectors were performed using ^{152}Eu and ^{241}Am radioactive sources. The resulting energy resolution using add-back for crystals within the same detector was 2.4 keV (FWHM) at 1085 keV.

3. Results and discussion

A singles γ-ray spectrum measured during the experiment is shown in figure 1 with transitions labelled according to the β decay they originate from. No major contaminants were observed except for the nuclei from the ^{182}Au decay chain.

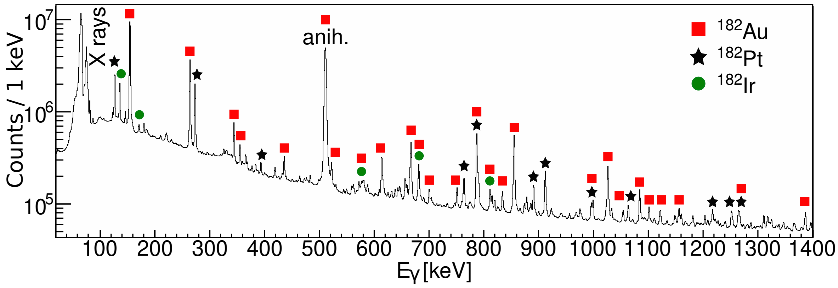

Fig. 1. (Colour on-line) A singles γ-ray spectrum of ^{182}Au EC/β^+ decay measured during the experiment. Transitions from the decay chain of ^{182}Au are marked: (■) decay of ^{182}Au, (★) decay of ^{182}Pt, and (●) decay of ^{182}Ir [17].

The assignment of γ-ray transitions to the β decay of ^{182}Au is based on γ–γ coincidences and on previously known transitions [9]. The prompt coincidence time window was set to 200 ns. Background subtraction of coincidence spectra was performed by gating on the close region outside the peak of interest. Figure 2 shows a γ–γ coincidence spectrum with the gate on the strongest line in ^{182}Pt, the 155-keV $2_1^+ \to 0_1^+$ transition.

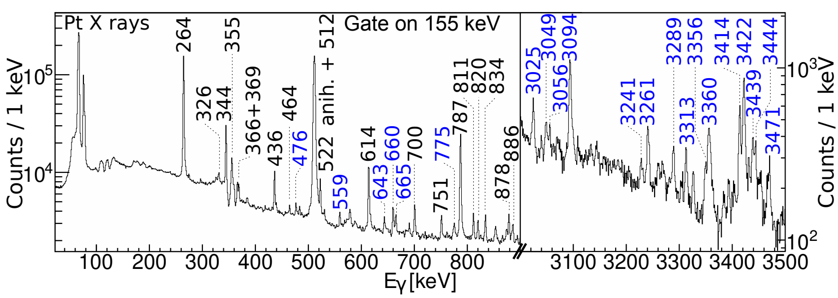

Fig. 2. (Colour on-line) A γ–γ coincidence spectrum gated on the 155-keV transition of ^{182}Pt. New transitions are highlighted in blue/grey.

We confirmed the currently known level scheme of ^{182}Pt from Ref. [9], with the exception of two γ-ray transitions (644 and 682 keV). These transitions were observed, although, based on γ–γ coincidences, we placed them at different positions in the level scheme.

In addition to the previously known transitions and levels, we observed about 200 new transitions and 80 new levels up to the excitation energy of ~ 3.7 MeV in ^{182}Pt. Relative intensities of the most intense γ-ray transitions were determined from the singles γ-ray spectrum. Intensities of the remaining transitions were determined from γ–γ coincidence spectra, as many of them could not be resolved in the singles γ-ray spectrum.

We evaluated the β-decay feeding intensities into excited states of ^{182}Pt on the basis of transition intensities, which were obtained from γ-ray intensities accounted for the internal conversion. Internal conversion coefficients (ICCs) were taken from Ref. [18]. Average values of ICCs for E1 and M2 multipolarities were used for transitions with unknown multipolarity. These values were chosen as the smallest and the largest ICCs amongst the E1, M1, E2, and M2 multipolarities considered for the prompt γ-ray transitions. Uncertainties were calculated as the difference between these two conversion coefficients divided by two. A correction for the β decay branching ratio of ^{182}Au $b_\beta = 99.87(5)\%$ [19] was taken into account. The total amount of ^{182}Au β decays was determined as the sum of transition intensities to the ground state of ^{182}Pt and used for normalisation of β-decay feeding intensities. Since the ground state of ^{182}Au has spin and parity $I^\pi = 2^+$ [20], we expect negligible direct β-decay feeding to the 0^+ ground state of ^{182}Pt.

The β-decay feeding intensities deduced in this work for several levels in ^{182}Pt are shown in Table 1. These values are influenced by the so-called Pandemonium effect [22]. High-lying excited states can be depopulated through the emission of several low-intensity and high-energy γ-ray transitions. Due to the low detection efficiency for high-energy γ rays, these transitions are often not observed in the experiment. This leads to the overestimation of β-decay feeding intensity, especially for relatively lower-lying levels. Therefore, the values of β-decay feeding in Table 1 are the apparent β-decay feeding intensities and should be considered as upper limits.

Table 1. Comparison of the previously known values of β-decay feeding intensities, $I_\beta^{\rm ref}$, and those determined in this work, I_β, into the previously selected known levels. Values of spin and parity I^π are taken from Ref. [9]. The previously known values of β-decay feeding intensity $I_\beta^{\rm ref}$ were calculated using transition intensities from Refs. [9, 21]. Values of I_β from this work were calculated from both the previously known (Known trans.) and the newly observed transitions (New trans.), column (Total) contains the sum of these values, see the text for details.

Level	I^π [9]	$I_\beta^{\rm ref}$ [9, 21]	I_β this work [%]		
[keV]		[%]	Known trans.	New trans.	Total
154.9	2^+	31(2)	26.4(9)	−12.2(3)	14.2(9)
667.5	2^+	10(2)	18.5(5)	−4.9(2)	13.6(5)
942.1	(3^+)	7.4(9)	8.5(2)	−3.7(1)	4.8(2)
1151.2	(0)	1.3(1)	0.63(4)	0.10(5)	0.72(6)
1181.4	(2)	4.9(5)	4.0(1)	−1.3(2)	2.7(2)
1311.0	2^+	1.8(3)	2.1(2)	0.69(5)	2.8(2)
1472.8		1.5(4)	1.4(1)	−0.02(3)	1.3(1)
1501.8		1.8(3)	0.92(4)	0.22(5)	1.1(1)
1541.6		0.8(2)	0.81(4)	0.72(10)	1.5(1)

Since we extended the level scheme of ^{182}Pt up to approximately twice the excitation energy compared to the previous study [9], the influence of the Pandemonium effect is decreased. However, it cannot be fully ruled out due to the high-Q value of this decay ($Q_{\mathrm{EC}} = 7868(24)$ keV [23]). In Table 1, we compare our values of β-decay feeding intensity, I_β, with the previously known values, I_β^{ref}, calculated using transition intensities from Refs. [9, 21]. The internal conversion was taken into account in the same way as for the values from this work. The values determined in our work were calculated separately from the previously known transitions and newly observed transitions. This separation allows us to evaluate the amount of β-decay feeding in the previous study that can be attributed to the Pandemonium effect.

In the previous work, the highest β-decay feeding was observed for the first 2^+ excited state at 155 keV, which was about three times stronger than for any other level. In our study, the feeding to this level is still the strongest, although it is now comparable to the feeding of the 2_2^+ state at 668 keV. This decrease in the β-decay feeding of the 155-keV level is mainly caused by the newly observed indirect feeding from higher-lying states, which decreases the deduced values of apparent direct β-decay feeding. In the case of the 668-keV level, the main difference stems from the change in the intensity of transitions between this study and the previous one rather than the observation of new transitions.

The β-decay feeding intensity of the most populated levels decreased with the observation of new transitions. However, for other levels, for example for the 1311.0- and 1541.6-keV states, we can see an increase in the β-decay feeding intensity. This increase is caused by the observation of the new transitions de-exciting these levels.

The amount of β-decay feeding into previously known levels makes about 68% of the total β-decay feeding deduced in this work. The remaining $\sim 32\%$ of the feeding leads to the newly observed levels, and thus in the previous study, it contributed to the Pandemonium effect. The influence of the Pandemonium effect is therefore significantly lowered.

4. Conclusion

We introduced partial preliminary results of our recent β-decay study of ^{182}Au into excited states in ^{182}Pt. Based on the γ–γ coincidence technique, we extended the level scheme of ^{182}Pt. Additionally, we determined transition intensities from the singles γ-ray and γ–γ coincidence spectra, which led to the evaluation of the apparent β-decay feeding intensities into excited states in this isotope. These values were compared with the intensity of β-decay feeding deduced from γ-ray intensities taken from the previous study of

^{182}Au β decay. Approximately 32% of observed direct β-decay feeding leads to newly assigned levels, which reduces the influence of the Pandemonium effect. The full results and discussions will be published elsewhere [12].

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