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Half-lives of platinum isotopes from photoactivation

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Abstract. The half-lives of the platinum isotopes ^{189,191,197}Pt and of the 4-day isomer in $^{195\mathrm{m}}$Pt have been measured with high precision using the photoactivation technique. The γ-ray activity was counted over several half-lives with a high-purity germanium detector. The measured half-lives are: $T_{1/2}(^{189}\mathrm{Pt}) = 12.1 \pm 1.5\,\mathrm{h}$; $T_{1/2}(^{191}\mathrm{Pt}) = 2.862 \pm 0.007\,\mathrm{d}$; $T_{1/2}(^{197}\mathrm{Pt}) = 19.96 \pm 0.05\,\mathrm{h}$; $T_{1/2}(^{195\mathrm{m}}\mathrm{Pt}) = 4.0104 \pm 0.0047\,\mathrm{d}$.

PACS. 21.10.Tg Lifetimes – 27.70.+q $150 \leq A \leq 189$ – 27.80.+w $190 \leq A \leq 219$

The half-lives of unstable platinum isotopes in the vicinity of the stable isotopes are known with high precision only in the case of ^{197}Pt [1,2]. However, for the isotopes ^{189,191}Pt and the 4-day isomer in ^{195}Pt there are considerable uncertainties from the previous measurements [2–7]. For a subsequent photoactivation experiment with a quasi-thermal photon spectrum at astrophysically relevant energies [8] a precise knowledge of the half-lives of these isotopes is necessary to avoid systematic errors in the data analysis, especially in the case when a relatively long time lies between the irradiation and the counting phase. Therefore, we have measured the half-lives of the platinum isotopes ^{189,191,197}Pt and of the 4-day isomer in ^{195}Pt by the decay curves of several γ-ray lines following the β^- decay (^{197}Pt), electron capture (^{189,191}Pt), and the deexcitation of the isomer ($^{195\mathrm{m}}$Pt).

The experiment was performed at the real photon facility of the superconducting Darmstadt linear electron accelerator S–DALINAC [9,10]. A platinum sample of about 800 mg with natural isotopic composition was irradiated with bremsstrahlung at an endpoint energy of 9.9 MeV for about 24 hours. The bremsstrahlung was produced by a continuous wave electron beam of 35 μA impinging on a rotating copper bremstarget. The distance between the bremstarget and the platinum sample was 62 mm. The platinum sample was activated mainly by (γ,n) reactions and by the (γ,γ') reaction in the case of the 4-day isomer in ^{195}Pt. The activity was counted after the irradiation using a high-purity germanium (HPGe) detector with a relative efficiency of 30% (relative to a 3" × 3" NaI(Tl) detector) and an energy resolution of 2.2 keV at the 1332.5 keV ^{60}Co line. A γ-ray spectrum is shown in Fig. 1.

Photon spectra were accumulated for two weeks with an automatic saving every hour leading to about 300 spectra for the analysis of the decay curves. The absolute time scale of the spectra was derived from the time standard which is distributed by the Physikalisch-Technische Bundesanstalt, Braunschweig, Germany, via a long-wave radio signal. The deadtime of the system consists mainly of the conversion time of the ADC (100 MHz Wilkinson type) and of the transfer time from the ADC to the computer. The deadtime per detected event was measured in dependence of the pulse height. The total deadtime per spectrum is given by the sum of the deadtime per event, and the result from the measured deadtime per event agreed exactly with the deadtime which is automatically determined by the data acquisition system. The yields in the spectra were corrected accordingly from 10.4% (first spectrum, total count rate 3500/s) to 0.2% (last spectrum, total count rate 65/s). Systematic uncertainties from the deadtime correction have been estimated to be of the order of less than 0.1%.

The main source of uncertainties comes from the simultaneous measurement of decay curves from many γ-ray lines with different half-lives because the background below the relevant peaks is thus also time dependent. The same problem will be present in the subsequent activation experiment [8]. The precise exponential decay of the γ-ray yields in this work confirms that no background lines disturb the analysis of the photoactivation spectra. One exception is the 4-day isomer in ^{195}Pt where a minor contribution from a weak γ-ray branch from the ^{191}Pt decay has been corrected in the 129.8 keV line.

The excellent resolution of the HPGe detector helps to reduce these systematic uncertainties for the most part because the presence of background lines can be determined already at energy differences less than 1 keV in the relevant area below about 500 keV.

The γ-ray spectra have been analyzed with the program package TV [11]. Different regions of interest for the peak areas and for the background calculation were chosen to check the consistency of the data analysis procedure, and the resulting uncertainties were typically of the order of less than 0.3% for each of analyzed γ-ray lines listed in

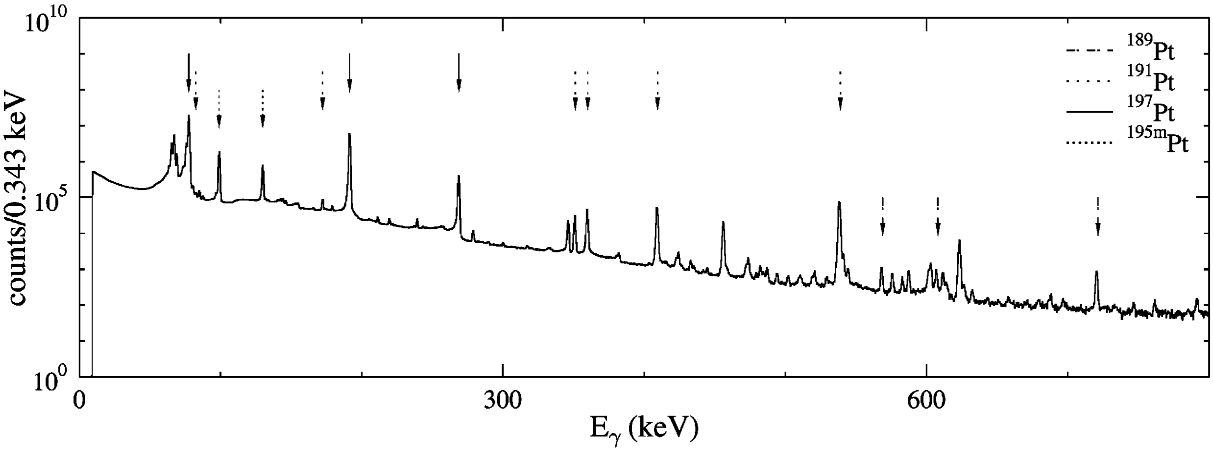

Fig. 1. Photon energy spectrum of the HPGe detector after irradiation of the ^{nat}Pt sample with bremsstrahlung at an endpoint energy of 9.9 MeV. Strong peaks from the decay of the different Pt isotopes are labelled, and most of the other lines are due to weak decay branches. The spectrum displayed here contains only a part of the total accumulated statistics of about one day because the peaks with short half-lives (from ^{189}Pt) disappear in the increasing background in the full spectrum

Table 1. In the cases where only one γ-ray line could be analyzed (^{189}Pt, ^{197}Pt) a systematic uncertainty of 0.3% (as discussed above) has been added quadratically to the statistical uncertainty of the measured half-life. For ^{191}Pt and ^{195m}Pt, where several decay curves could be observed, it turned out that the measured half-lives from the different γ-rays were internally consistent, and a smaller systematic uncertainty of 0.1% was added quadratically to the weighted average of the different results.

A comparison of our new results with the adopted half-lives shows an overall good agreement as can be seen in the overview over our present results (Table 1). Two examples of the measured decay curves are shown in Fig. 2 for ^{191}Pt and ^{195m}Pt. In the following we discuss our results and illustrate the differences to previous measurements.

(i) ^{189}Pt: Our new result 12.1 ± 1.5 h agrees within the uncertainties with the adopted value [2,3] from [12], and the adopted value is identical to the weighted average of several previous results listed in [2,3]. Unfortunately, the statistics in our experiment is by far not sufficient to improve the adopted value of 10.87 ± 0.12 h because of the very low natural abundance of ^{190}Pt of 0.01%.

(ii) ^{191}Pt: The measured half-life of 2.862 ± 0.007 d (see also Fig. 2) is slightly higher than the previous measurement 2.802 ± 0.025 d of [13] which has been adopted in [2]. However, the adopted value in the Nuclear data sheets, which is the weighted average of many previous experiments, is 2.96 ± 0.04 d [4], which is slightly higher than our new result. The weighted average of the previous results is mainly determined by the result of 3.00 ± 0.02 d from [14]; excluding the value of [14], one obtains a weighted average of 2.84 ± 0.04 d in excellent agreement with our new result. It should be noted that a similar situation appears for the half-life of the 4.33-d isomer of ^{193}Pt: a half-life of 4.33 ± 0.03 d was found in [14], again larger than the weighted average of 3.71 ± 0.15 d from several other results [2,5]. Unfortunately, the decay of the 4.33-d isomer in ^{193}Pt cannot be seen in our experiment because there is no detectable γ-ray from its decay and it is practically not populated in the ^{194}Pt(γ,n) reaction because of its high spin of $J^\pi = 13/2^+$.

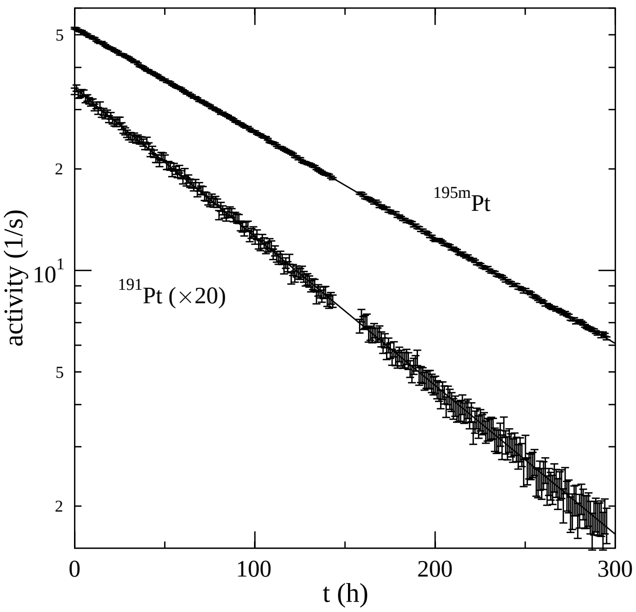

Fig. 2. Decay curves of the activities of the 409.4 keV line from the decay of ^{191}Pt (lower line) and of the 98.9 keV line from ^{195m}Pt (upper line). The data for ^{191}Pt have been multiplied by a factor of 20. The missing data points at $t \approx 150$ h are the consequence of a general failure of electric power in a thunderstorm over Darmstadt in the night from 20th to 21st of July, 1999

(iii) ^{197}Pt: The measured half-life of 19.96 ± 0.05 h agrees within the uncertainties with the high-precision measurement of [1]. Previous results [2,7] vary from 17.5 to 20.0 hours with larger uncertainties.

(iv) ^{195m}Pt: The measured half-life of 4.0104 ± 0.0047 d (see also Fig. 2) agrees within the uncertainties with the adopted value [2,6] which is based on a private commu-

Table 1. Measured half-lives of the platinum isotopes ^{189}Pt, ^{191}Pt, ^{197}Pt, and ^{195m}Pt, compared to the adopted values from the ENSDF data base [2]

nuclide	decay	E_γ (keV)	$T_{1/2}$ [1]	$T_{1/2}$ [2]
^{189}Pt	ϵ	721.4	12.1±1.5 h	10.87±0.12 h
^{191}Pt	ϵ	weighted average: [3]	2.862±0.007 d	2.802±0.025 d [4]
		172.2	2.886±0.050 d	
		351.2	2.852±0.029 d	
		360.0	2.884±0.009 d	
		409.4	2.842±0.009 d	
		538.9	2.840±0.026 d	
^{197}Pt	β^-	191.4 [1]	19.96±0.05 h	19.8915±0.0019 h
^{195m}Pt	γ	weighted average: [3]	4.0104±0.0047 d	4.02±0.01 d
		98.9	4.0097±0.0027 d	
		129.8	4.0129±0.0050 d	

[1] this work
[2] adopted values, from [2]
[3] including an additional systematic uncertainty of 0.1%
[4] $T_{1/2} = 2.96 \pm 0.04$ d adopted in Nuclear Data Sheets [4]

nication ([15]). We have reduced the uncertainty of the half-life of ^{195m}Pt slightly compared to [15]. The weighted average of the previous results [2] is 4.16 ± 0.06 d which is in rough agreement with the adopted value and our new result.

In conclusion, we have measured the half-lives of several platinum isotopes over several half-lives with an accuracy better than 1%. In particular, we have been able to resolve the problem of the contradictory adopted values of [2,4] for the half-life of ^{191}Pt, and our new result lies between the two previously adopted values. Furthermore, we have improved the accuracy of the result for ^{195m}Pt, and we confirm the adopted half-lives for ^{189}Pt and ^{197}Pt.

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