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Half-Life Determination for ^{108}Ag and ^{110}Ag

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Abstract. In this work, the half-life of the short-lived silver radionuclides ^{108}Ag and ^{110}Ag were measured by following the activity of samples after they were irradiated in the IEA-R1 reactor. The results were then fitted using a non-paralizable dead time correction to the regular exponential decay and the individual half-life values obtained were then analyzed using both the Normalized Residuals and the Rajeval techniques, in order to reach the most exact and precise final values. To check the validity of dead-time correction, a second correction method was also employed by means of counting a long-lived ^{60}Co radioactive source together with the samples as a livetime chronometer. The final half-live values obtained using both dead-time correction methods were in good agreement, showing that the correction was properly assessed. The results obtained are partially compatible with the literature values, but with a lower uncertainty, and allow a discussion on the last ENSDF compilations' values.

Keywords: half-life;Ag-108;Ag-110
PACS: 23.40.-s

INTRODUCTION

Nuclear applications usually require a good degree of knowledge on several parameters of the nuclei involved, both regarding the safety of the experiment and the reliability of the results. For instance, in Nuclear Activation Analysis (NAA), many nuclear parameters, such as cross section, transition intensities and decay half-life, have to be well known in order to compute the results, and the uncertainties in these parameters frequently undermine the results obtained in the analyzes [1]. In the instrumental variation of NAA, which relies on the use of a well known comparator irradiated together with the samples in order to eliminate most of the nuclear parameters from the equations, the value of the decay half-life is still an important parameter and it appears inside an exponential function, so its uncertainty must be carefully assessed because it may distort the results of the whole analysis.

In the case of Silver, there are only two stable isotopes, ^{107}Ag and ^{109}Ag, and the activation of them result in two short-lived radioisotopes, ^{108}Ag ($T_{1/2} = 142.2(6)$s [2]) and ^{110}Ag ($T_{1/2} = 24.56(11)$s [3]). In this work, the decay of these isotopes was studied by following the activity decay in neutron-irradiated natural Silver samples.

EXPERIMENTAL PROCEDURE

In the present experiment, samples were produced by pipetting $70\mu L$ of a 1.010 g.L^{-1} Silver standard solution on pieces of Whatman 40 filter paper; the samples were left to dry naturally and then folded and packed into sealed polyethylene bags. These samples were then irradiated for a few (4-10) seconds in the IEA-R1 nuclear reactor under a thermal neutron flux of $\sim 5 \times 10^{12}$ n·cm^{-2}·s^{-1} using a fast pneumatic irradiation facility (sample transit time $\sim$ 10s) and then analyzed by a 25% HPGe detector coupled to a 8192-channel MCA with a source-detector distance of 9 cm. The data collection for each individual sample was made through a batch of short subsequent acquisitions with identical realtime duration; both radionuclides were measured in each irradiation, but in order to favour the measurement towards one or the other the counting times varied from $40 \times 10s$ to $20 \times 40s$. The determination of the shorter-lived ^{110}Ag isotope was performed using the 657keV γ transition, and the determination of ^{108}Ag used the 633keV γ transition – the area of the latter was only regarded from the point where the 657keV transition could not be determined anymore, in order to reduce dead-time issues and allow for a better correction.

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DATA ANALYSIS

For the determination of the half-lives, the gamma-ray spectrum for each individual acquisition was analyzed using the Genie-2000 computer software [4], which delivers reliable and accurate peak areas for standard gamma spectra [5]. The counts per second associated with each decay were fitted against the initial time of each acquisition using the non-paralyzable dead-time correction model shown in Eq. 1 [6], where A_0 (the initial count rate), λ ($= \ln(2)/T_{1/2}$ where $T_{1/2}$ is the nuclide half-life) and τ (the dead time parameter) were the fit parameters. The fit was performed using a covariant Gauss-Marquardt routine implemented in the MatLab environment. A total of 19 measurements were made for each of the two isotopes.

$$A = \frac{A_0 \cdot e^{-\lambda t}}{1 + A_0 \cdot \tau} \tag{1}$$

In order to validate the dead-time correction, a second dead-time correction was performed by counting a 30kBq ^{60}Co source, with a much longer half-life (1925.28(14) days [7]) together with the samples as a "live-time chronometer", so the counts obtained for the interest isotope's peak were divided by the sum of the areas of the 1173 and 1332 keV peaks of the ^{60}Co decay, and the result was fitted to a regular exponential decay function.

The results obtained were then analyzed using the regular arithmetic (unweighted) and σ^{-2}-weighted means as well as two techniques designed specifically for the analysis of discrepant data, the *Normalized Residuals* and the *Rajeval Technique* [8], in order to obtain a more robust final value which would not be too influenced by eventual outlier results.

RESULTS

The results obtained in each of the individual measurements for the half-life of the Silver isotopes using the ^{60}Co correction are shown in Fig 1, together with the ENSDF compilation values; Table 1 shows the final average results using both dead-time corrections. It must be noted that both the mathematical and the experimental dead-time corrections led to absolutely compatible results, evidencing that dead-time is well taken care of; as the use of a long-lived radioisotope is a more robust and primary method of correction, the discussion will focus on the results obtained with it. Likewise, as all three weighted statistical tools led to almost identical results, the results obtained using the Rajeval technique will be the ones taken into consideration.

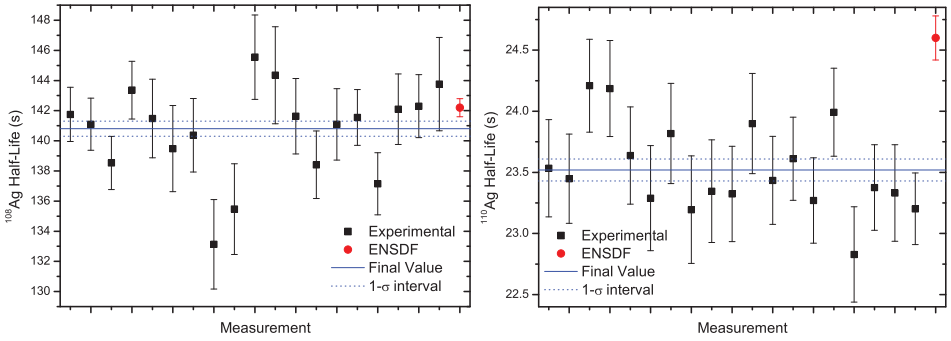

FIGURE 1. Results of each of the individual measurements for the half-life of ^{108}Ag (left) and ^{110}Ag (right) using the ^{60}Co correction, together with the ENDS compilation values (in red, from [2] and [3], respectively); the full lines represent the result of the Rajeval average and the dotted lines the $1-\sigma$ interval.

The result obtained for the half-life of ^{108}Ag presents an uncertainty of the same magnitude as the ENSDF [2] value, but is only compatible with it within a 2σ interval; nevertheless, the present result is compatible with the most recent and precise measurement of 141.2(5)s [9], while the other results used in the compilation are from 1974 or older. This is an indication that the ENSDF value should be reassessed.

As for the half-life of ^{110}Ag, the present result has a smaller uncertainty, but is well below the ENSDF value [3]; the latter, though, is the result of a weighted average of old measurements (the most recent is from 1970) that mostly present quite large uncertainties, so there's some indication that the ENSDF value probably has a somehow underestimated uncertainty and should be reassessed, too.

TABLE 1. Results of the averages for the half-lives of ^{108}Ag and ^{110}Ag using each of the dead-time correction methods (DTC) - *Math.* stands for the mathematical non-paralizable correction and ^{60}*Co* for the one using the long-lived radioisotope as livetime chronometer; *AM*, *WM*, *NR* and *RT* are the arithmetic, σ^{-2}-weighted, Normalized Residuals and Rajeval averages, respectively.

Nuclide	DTC	AM (s)	WM (s)	NR (s)	RT (s)	Ref. (s)
^{108}Ag	Math.	139.6 (9)	141.2 (6)	141.2 (6)	141.2 (6)	142.2 (6) [2]
	^{60}Co	140.7 (7)	140.8 (5)	140.8 (5)	140.8 (5)	
^{110}Ag	Math.	23.51 (10)	23.48 (6)	23.48 (6)	23.47 (6)	24.56 (11) [3]
	^{60}Co	23.52 (8)	23.52 (9)	23.52 (9)	23.52 (9)	

CONCLUSIONS

The two independent dead-time correction methods employed delivered equivalent results in both cases, indicating that the dead-time effects are properly taken care of.

The results obtained for the half-lives of the silver isotopes of masses 108 and 110 presented uncertainties lower or of the same order of magnitude than the ENSDF compilations, but in both cases the results were not perfectly compatible with the compiled values. In both cases, the compilations relied on old (pre-1975) experimental results with somehow large uncertainties, with the averaging procedure resulting in low, but seemingly unreliable, uncertainties. This is an indication that the ENSDF value for both nuclides should be reassessed.

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