HORIZON 2020

HORIZON 2020 RESEARCH AND INNOVATION FRAMEWORK PROGRAMME OF THE EUROPEAN ATOMIC ENERGY COMMUNITY

Nuclear Fission and Radiation Protection 2018 (NFRP-2018-4)

Project acronym: **SANDA**

Workpackage N°: ***WP2***

Identification N°: ***D2.15***

Type of document: ***Deliverable***

Title: **Report on the of half-live and gamma-ray emission probabilities of beta emitters measurement**

Dissemination Level: ***PU***

	Name	Partner	Date	Signature
Prepared by:	M.A. Kellett	3	11-06-2024	Digitally signed by KELLETT Mark Date: 2024.07.02 10:24:18 +02'00'
WP leader:	D. Cano-Ott	1	11-06-2024	Firmado por CANO OTT DANIEL - DNI ***8222** el día 02/07/2024 con un certificado emitido por AC Sector Público
IP Co-ordinator:	E. González	1	11-06-2024	Signed by GONZALEZ ROMERO ENRIQUE MIGUEL - DNI ***3708** at 02/07/2024 with a certificate isued by AC Sector Público

GRANT AGREEMENT

NUMBER 847552 — SANDA

Deliverable 2.15

Report on the of half-live and gamma-ray emission probabilities of beta emitters measurement

Measurement of the half-life for two radionuclides – proof of concept

^{51}Cr

The currently recommended half-life, according to the Decay Data Evaluation Project, is 27.704 (4) d [1].

A measurement was made at the CEA/LNHB with the newly installed ionisation chamber dedicated for this purpose and previously reported within this project. The Centronic IG11 was used to measure the half-life of a sample of ^{51}Cr between June and December 2022, corresponding to approximately six half-lives. The radioactive solution of ^{51}Cr was supplied by POLATOM (Poland) as part of the EURAMET 1554 project, as a 5 mL ampoule.

Current measurements were carried out with a Keithley 6517B electrometer with a series of 200 points acquired over a period of approximately 25 s and repeated every 6 h. Current values ranged from -24 pA to -0.4 pA (i.e. around 10 times the value of the background). If we refer to the publication by Pommé et al., 2018 [2], the range of currents measured is below the range change presenting a strong non-linearity (200 pA).

Data processing was implemented using a program for reading measured currents and associated time stamps, written by the CEA/LNHB. Estimation of the radioactive half-life was implemented by fitting the data with the decay formula, and imposing or not the current corresponding to the background measurement (5.5 (5) 10^{-2} pA).

An initial estimate was carried out on all measurements without imposing the current corresponding to the background. In this case, the radioactive half-life given by the adjustment is equal to 27.694 (6) d, and the estimate of the background (5.6 10^{-2} pA) is compatible with the measured value. In the following, the measured value of the background was imposed in the data fitting.

Another method consisted in performing an individual estimation on each measured dataset (7 in total) to check for a temporal trend in the measurements or an influence of linearity. The values obtained for the first 6 measurement periods are shown in Figure 1 and Table 1. A new estimate of the radioactive half-life equal to 27.686 (12) d is obtained by applying a weighted average to the 7 values obtained for each measurement period. The uncertainty obtained is greater than that previously obtained and will be used as a "medium frequency" uncertainty according to the methodology described by Pommé, 2015 [3].

Table 1: Individual and cumulative estimations of the radioactive half-life of ^{51}Cr considering different measurement durations

Measurement duration	Current range measured		Individual estimation	Cumulative estimation
8.5 d	- 24 pA	- 15.7 pA	27.65 (3) d	27.65 (3) d
35.9 d	- 15.7 pA	- 6.12 pA	27.687 (15) d	27.695 (7) d
72.9 d	- 6.12 pA	-2.5 pA	27.71 (3) d	27.695 (5) d
97.8 d	- 2.5 pA	- 1.8 pA	27.96 (22) d	27.696 (5) d
114.0 d	- 1.8 pA	- 1.1 pA	27.95 (24) d	27.696 (4) d
137.0 d	- 1.1 pA	- 0.6 pA	27.69 (20) d	27.695 (4) d
160.9 d	- 0.6 pA	- 0.4 pA	27.64 (53) d	27.695 (4) d

A third method consisted in implementing the adjustment successively, accumulating the data from the different measurement periods one by one. The values obtained can also be seen in Table 1 and Figure 1. Due to the high weighting of the first 3 measurement periods, no significant variations were observed.

In the end, the radioactive half-life obtained is 27.695 (17) d, taking all measurements into account. The relative residuals as a function of time can be seen in Figure 2. The uncertainty budget is detailed in Table 2. The value is compatible with that recommended by the DDEP.

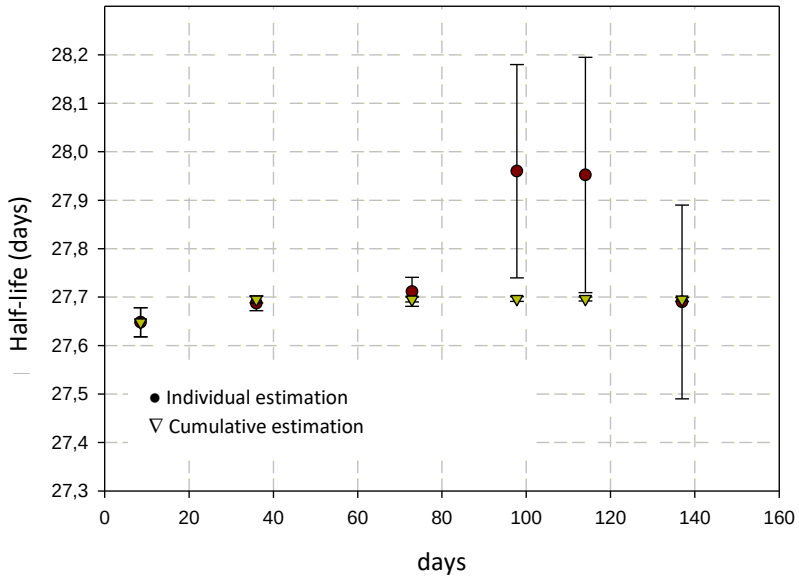

Figure 1 : Individual and cumulative estimations of the radioactive half-life of ^{51}Cr considering different measurement durations

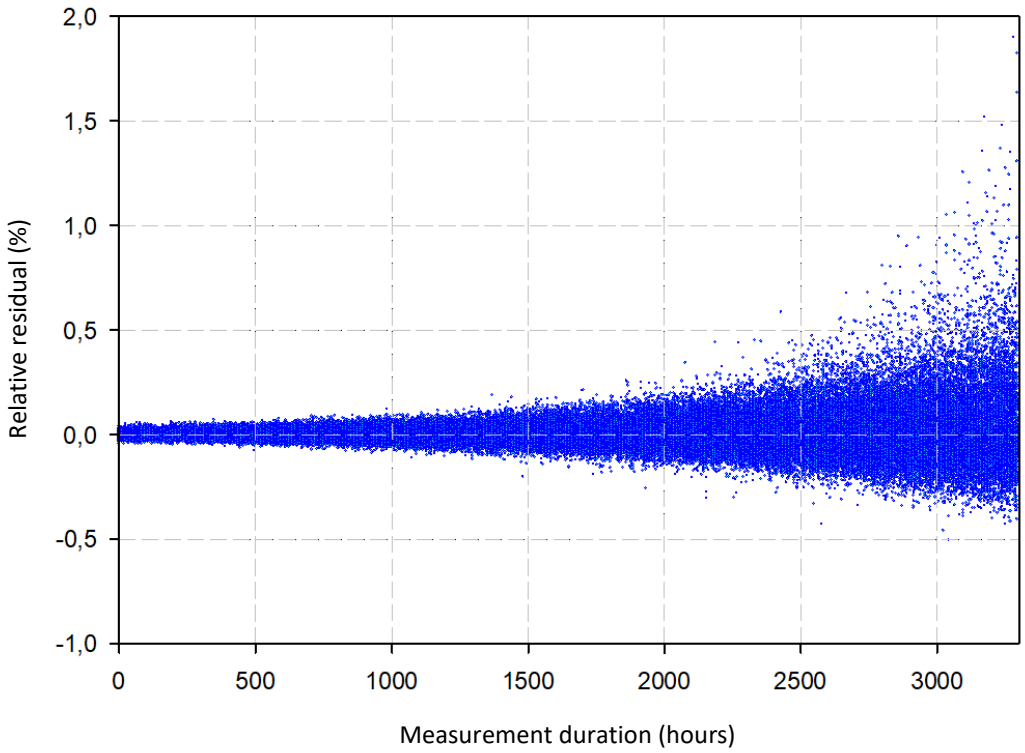

Figure 2 : Relative residuals as a function of the measurement duration of the half-life measurement of ^{51}Cr

Table 2: Uncertainty budget of the radioactive half-life measurement of ^{51}Cr

Component	$u(T_{1/2})$ / %
Statistical	0.02
Time variation and linearity	0.04
Background correction	0.04
Relative uncertainty	0.06

^{67}Ga

The recommended half-life of ^{67}Ga from the Decay Data Evaluation Project is 3.2613 (5) d [1]. The measurement of the half-life with the Centronic IG11 chamber was carried out between January and March 2023 with a ^{67}Ga radioactive solution supplied by Curium.

Current measurements were carried out with a Keithley 6517B electrometer as a series of 200 points acquired over a period of approximately 25 s and repeated every 10 minutes. Current values ranged from -4.26 nA to -0.1 pA. The range of measured currents is wider than that obtained when measuring the radioactive half-life of ^{51}Cr, and in particular includes the range change exhibiting strong non-linearity below -200 pA.

Table 3: Individual and cumulative estimations of the radioactive half-life of ^{67}Ga considering different measurement durations

Measurement duration	Current range measured		Individual estimation	Cumulative estimation
1.62 d	- 4.27 nA	- 2.34 nA	3.26198 (15) d	3.26198 (15) d
4.44 d	- 2.34 nA	- 1.28 pA	3.26115 (20) d	3.26166 (6) d
7.26 d	- 1.28 nA	- 0.705 nA	3.26014 (27) d	3.26143 (4) d
10.07 d	- 705 pA	- 387 pA	3.26089 (38) d	3.26129 (3) d
12.89 d	- 387 pA	- 212.2 pA	3.26105 (56) d	3.26114 (3) d
15.71 d	- 212.1 pA	- 116.2 pA	3.26357 (39) d	3.26112 (2) d
18.53 d	- 116.1 pA	- 63.7 pA	3.26362 (41) d	3.26111 (2) d
21.35 d	- 63.6 pA	- 35 pA	3.26065 (57) d	3.26111 (2) d
24.17 d	- 34.9 pA	- 19.2 pA	3.26151 (82) d	3.26111 (2) d
27.00 d	- 19.1 pA	- 10.05 pA	3.2578 (12) d	3.26111 (2) d
29.81 d	- 10.05 pA	- 5.74 pA	3.2611 (19) d	3.26111 (2) d
32.63 d	- 5.74 pA	- 3.18 pA	3.2578 (30) d	3.26111 (2) d

Data processing was carried out in a similar way to that applied in the case of ^{51}Cr. Estimation of the radioactive half-life was implemented by fitting the data with the decay formula, imposing the current corresponding to the measurement of the background (5.5 (5) 10-2 pA). Temporal variability and the influence of the linearity of the electrometer response were analyzed by considering several measurement periods of 2.8 d duration to obtain 5 half-lives between the maximum current at - 4.26 nA and the range change at - 200 pA. In total, the analysis of the radioactive half-life of ^{67}Ga was carried out by considering 12 time intervals of 2.8 d for a current range between - 4.26 nA and - 3 pA.

The results obtained for individual and cumulative estimates are shown in Table 3. The individual estimates are also reproduced in Figure 3, which shows the influence of the electrometer range change at a current of -200 pA. From the data in Table 3, we can derive 4 values for the radioactive half-life of ^{67}Ga:

- by calculating the weighted average of the 5 individual estimates corresponding to currents between - 4.26 nA and - 200 pA: $T_{½}$ = 3.26137 (10) d ;
- taking the estimate for the first 5 cumulative periods: $T_{½}$ = 3.26114 (3) d ;
- by calculating the weighted average of all individual estimates: $T_{½}$ = 3.26158 (9) d ;
- by taking the estimate for all cumulative periods: $T_{½}$ = 3.26111 (2) d. The evolution of the residuals as a function of time can be seen in Figure 4.

Estimates obtained from cumulative periods give lower uncertainties that do not take into account temporal variations or an influence of the electrometer's linearity. Given the different results and associated uncertainties, the value adopted is that given by the weighted average of the 5 individual estimates: $T_{½}$ = 3.26137 (46) d. A conservative value of 0.01% is associated with the "medium frequency" uncertainty. The uncertainty budget is shown in Table 4. The measured half-life is compatible with that recommended by the DDEP.

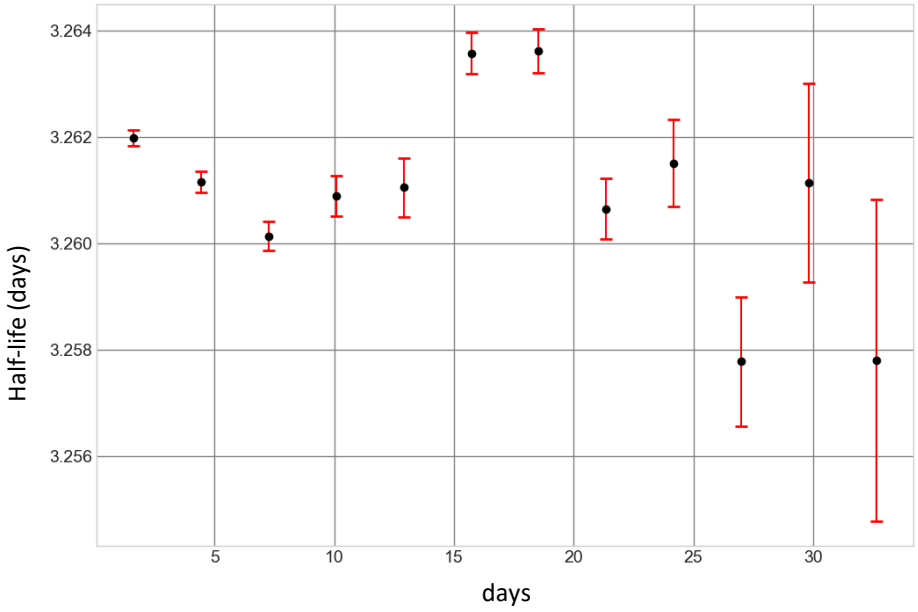

Figure 3 : Individual estimations of the radioactive half-life of ^{67}Ga considering different measurement durations

Table 4: Uncertainty budget of the radioactive half-life measurement of ^{67}Ga

Component	$u(T_{½})$ / %
Statistical	0.003
Time variation and linearity	0.01
Background correction	0.01
Relative uncertainty	0.014

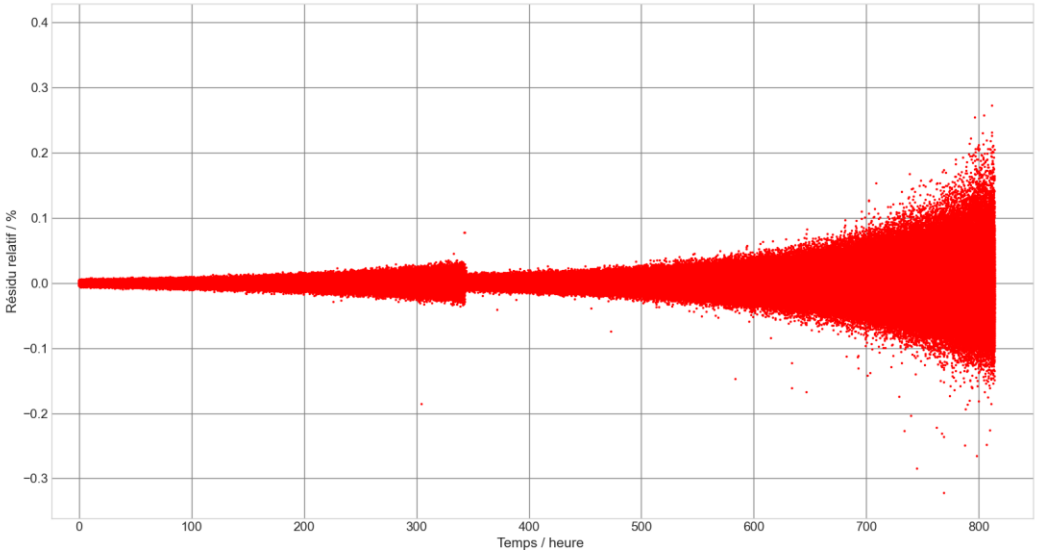

Figure 4 : Relative residuals as a function of the measurement duration. The gain change of the electrometer at - 200 pA is clearly visible

Discussion

Radioactive half-life values for ^{51}Cr and ^{67}Ga were obtained from direct current measurements with the electrometer. These measurements are sensitive to the linearity of the device. This problem can be reduced by measuring the voltage at the terminals of a capacitor as a function of charging time, enabling a current to be deduced from the slope. This technique was used to measure the radioactive half-life of ^{166}Ho at CEA/LNHB, and did not show a strong influence of the electrometer's linearity [2].

References

[1] M.-M. Bé, et al., Monographie BIPM-5, Vol.1, Bureau International des Poids et Mesures (2004)

[2] S. Pommé, *et al.*, *Linearity check of an ionisation chamber through 99 mTc half-life measurements*, Appl. Radiat. Isot. **140** (2018) 171-178

[3] S. Pommé, *The uncertainty of the half-life*, Metrologia **52** (2015) S51-S65

[4] C. Bobin, *et al., Activity measurements and determination of nuclear decay data of ^{166}Ho in the MRTDosimetry project*, Appl. Radiat. Isot. **153** (2019) 108826