



Determination of the activity of iodine-125 by the sum peak method for application in brachytherapy

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1. Introduction

Investigation around the iodine-125 radionuclide is interesting due to its diverse applicability in medical procedures, particularly in brachytherapy [1]. This radioisotope can be obtained through nuclear reactors; however, this process leads to the simultaneous formation of iodine-126, an undesired byproduct. The present study aims to calculate the activity of iodine-125 using the peak-sum method, intending to contribute to a thorough assessment of iodine-125 contamination by iodine-126. This investigation is crucial, considering the specific application of iodine-125 in seeds intended for the therapeutic treatment of cancer, aiming to ensure their purity and effectiveness, utilized in clinically relevant medical procedures [2].

2. Methodology

In this work, the radionuclide of interest is obtained by irradiating capsules containing xenon-124 gas in the IEA-R1 reactor, where the (n,γ) reaction forms xenon-125, which decays into iodine-125. However, depending on the irradiation time, the formation of the contaminant iodine-126 occurs. It is noteworthy that the half-life of iodine-125 is 59.4 days, while that of iodine-126 is 13.11 days.

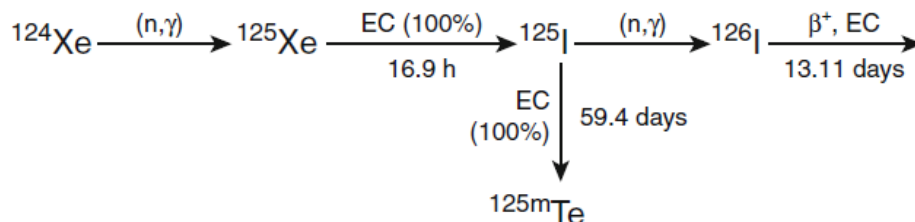


Figure 1: Production scheme of iodine-125 [3].

The characteristic gamma rays of radionuclides are measured using High Purity Germanium (HPGe) detector ORTEC GEM-C5970-B with 38% efficiency for ⁶⁰Co (at the energy of 1332 keV) and a resolution (FWHM) of 900 eV for ⁵⁷Co (at the energy of 122 keV). Due to the high intensity of iodine-125, the summing effect is observed in the acquisition spectra. This effect occurs when two gamma photons interact almost simultaneously with the detector, and the total energy of these photons is recorded as a single detection signal. Figure 2 displays a spectrum obtained through Maestro software, illustrating the presence of the summing peak effect.

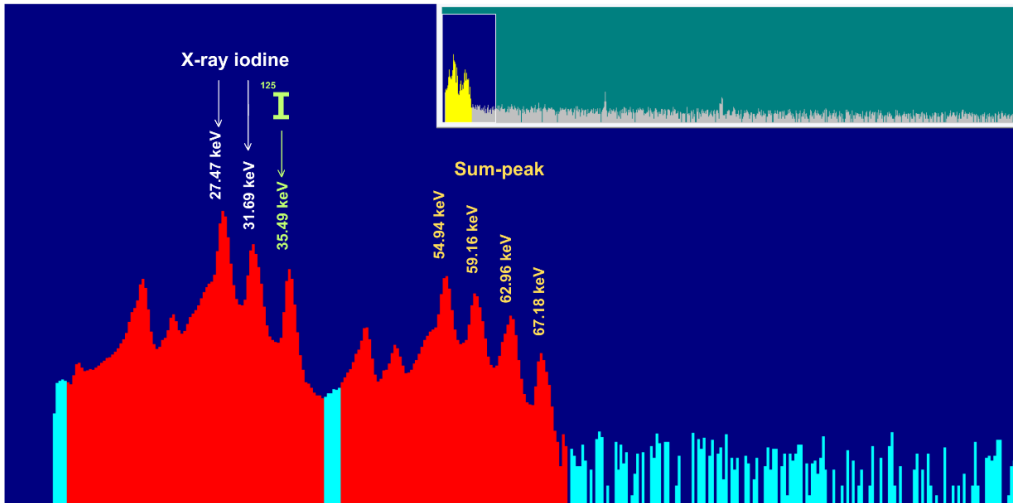


Figure 2: Iodine-125 spectrum with sum peak effect, with samples irradiated for 32 hours and a measurement time of 3600 s.

To determine the activity of iodine-125, it is necessary to use the following equation for correcting the sum peak [4]:

$$N_0 = \frac{P_1 P_2}{(P_1 + P_2)^2} \frac{(A_1 + 2A_2)^2}{A_2} \quad (1)$$

Where A_1 and A_2 are the counting rates corresponding to the first and second sum peaks, P_1 is the probability of electron capture emission, and P_2 is the probability of X-ray emission through internal conversion, added to the probability of emission of the 35.49 keV gamma energy from iodine-125. There is no sum peak effect for the gamma rays of iodine-126; therefore, another method (efficiency curve) is required for determining its activity. In the spectrum, the sum effect for iodine-126 gamma rays is not observed, therefore it is necessary to use another method for determining its activity, through the efficiency curve. Figure 3 represents the overall spectrum, including iodine-126.

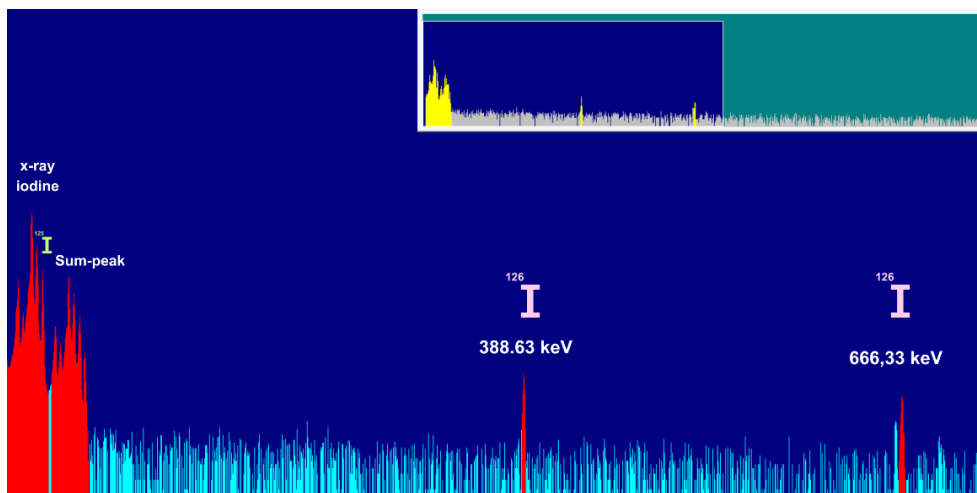


Figure 3: Spectrum of iodine-125 and iodine-126, with sample irradiated for 32h and measurement time of 3600 s.

To determine the activity of iodine-126, it is necessary to use the following equation for peak efficiency [5]:

$$A = \frac{S(E)}{\varepsilon_i(E) A T I_\gamma f_C f_\tau f_G f_A} \quad (2)$$

Where A is the activity of the standard at the time of measurement, $S(E)$ is the area under the total absorption peak of energy E , T is the measurement time (live time), I_γ is the absolute gamma intensity of the considered energy, f_τ is the dead time correction factor, f_A is the attenuation factor in the source casing, f_G is the correction factor for measurement geometry, and f_C is the correction factor for cascade summing effect.

3. Results and Discussion

Two samples were irradiated. The first one for an irradiation time of 32 hours, starting on July 11, 2023, and the second one for 16 hours, starting on August 15, 2023. Both had a measurement time of 3600 s. The activities of samples 1 and 2 were determined by correcting for the sum peak in relation to iodine-125. The results are presented in Tables I and II, respectively:

Table I: Determination of the activity of the sample irradiated on 11/07/2023 (irradiation time = 32 h).

Measurement date	Activity (Bq)	SD (Bq)	Activity (Ci)	SD (Ci)
25/07/2023	2267.29	6.51	612.78E-10	1.76E-10
26/07/2023	2201.51	6.38	595.00E-10	1.72E-10
19/09/2023	1123.02	7.58	303.52E-10	2.05E-10
09/11/2023	633.08	2.19	171.10E-10	0.59E-10
20/12/2023	414.38	2.78	111.99E-10	0.75E-10
05/02/2024	219.95	1.14	59.45E-10	0.31E-10

Table II: Determination of the activity of the sample irradiated on 15/08/2023 (irradiation time = 16h).

Measurement date	Activity (Bq)	SD (Bq)	Activity (Ci)	SD (Ci)
22/08/2023	1024.20	3.26	276.81E-10	0.82E-10
01/09/2023	908.65	4.83	245.58E-10	0.13E-10
19/09/2023	754.67	5.90	203.97E-10	1.59E-10
09/11/2023	372.99	1.52	100.81E-10	0.41E-10
19/12/2023	212.29	2.21	57.37E-10	0.60E-10
05/02/2024	118.71	0.73	32.09E-10	0.20E-10
06/02/2024	166.77	1.79	45.07E-10	0.49E-10

In Figure 4, the activities determined in Tables 1 and 2 are represented. The half-life ($T_{1/2}$) of iodine-125 was also obtained through linear regression analysis.

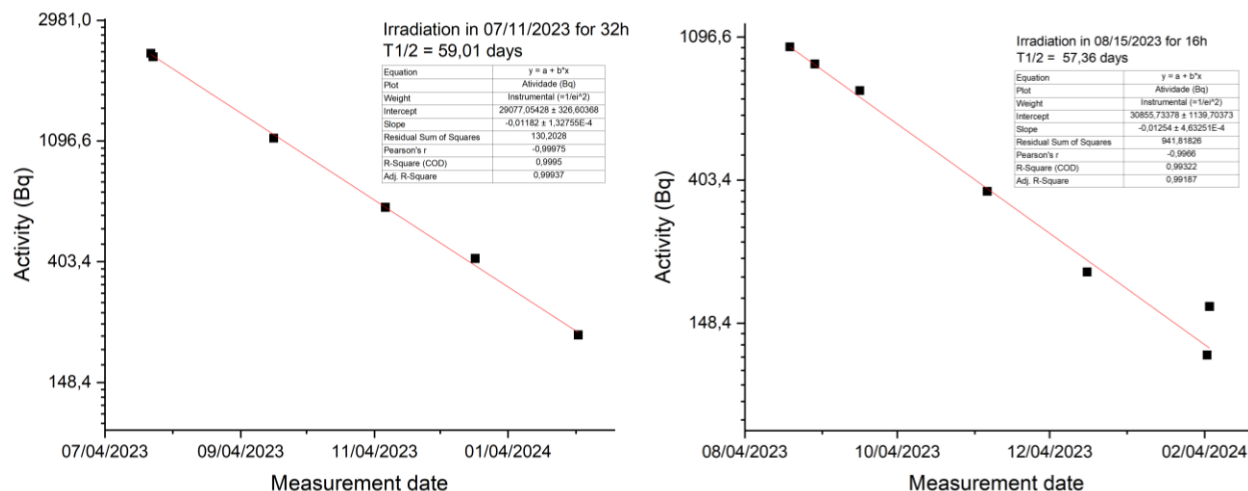


Figure 4: Determination of activities and half-life using the peak-sum method.

4. Conclusions

The determination of iodine-125 activity using the peak-sum method had satisfactory results, validated by obtaining the half-life of iodine-125. In the field of medical physics, it is essential to determine the activity of this radionuclide due to its applications in brachytherapy, ensuring the correct amount is administered to patients. The next steps involve calculating the activity of iodine-126 and determining its ratio relative to iodine-125.

Acknowledgements

Acknowledgment to the agencies FAPESP 2017/50332-0, CAPES 88887.667254/2022-00, CNEN and IAEA BRA-6062 for project funding and scholarship support.

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