Determination of X- and gamma-ray emission intensities in the decay of I-131

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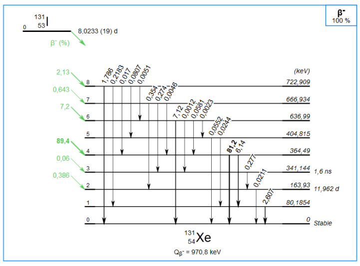
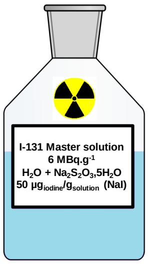
Iodine-131 is a fission product which can be released into the atmosphere during an accident scenario. Moreover it has been used for many years for medical purposes, mainly for thyroid diseases. Due to the high volatility of iodine, these isotopes are mobile in the environment and must be monitored.

For these reasons, I-131 has been extensively studied since the early sixties. However, the knowledge of the decay scheme is still poor, and the results obtained in earlier work exhibit a large dispersion and high uncertainties.

I-131 decay scheme and source preparation



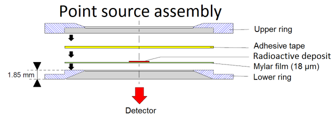


8 sources for 4π-γ counting + 7 for gamma spectrometry: Weighed deposit of the I-131 solution on Mylar® film with preliminary deposit of $AgNO_3$ to avoid the loss of iodine during the drying step.

$$Ag^{+}_{(aq)} + I^{-}_{(aq)} \rightarrow AgI_{(s)}$$

14 sources for coincidence counting: Weighed deposit of the I-131 solution on gold-coated VYNS + electrosprayed Estapor® Latex microspheres.

Point source assembly



Source for coincidence counting

Activity measurements

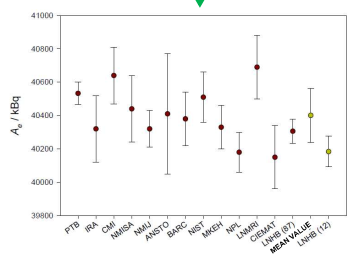
4π β-γ coincidence method

Activity concentration: 5.869 (15) MBq.g^{-1}

- **β-channel: pill-box proportional counter** (CH_4 at atmospheric pressure).
- **γ-channel: 3" × 3" NaI(Tl)** scintillator detector.
- **Efficiency-extrapolation** technique addition of multiple gold-coated VYNS foils.
- Coincidence counting using a **γ-window** (200 keV < E< 800 keV).

Using this setting, the ratio N_c/N_γ varied between 0.93 and 0.98.
(N_c: coincidence counting rate, N_γ: γ-counting rate)

At the reference date:
Activity concentration: 5.870 (23) MBq.g^{-1}
Value sent to BIPM for SIR comparison



SIR results (equivalent activity)

4πγ counting method

Activity concentration: 5.874 (23) MBq.g^{-1}

Detector: large well-type NaI(Tl)

Counting system: based on separate NIM modules:

- Amplifier + MTR2 discriminator (based on extendable dead time and live-time technique).
- ADC → energy histogram used to estimate the zero-energy extrapolation correction.
- Dual counter/timer for counting and live-time measurements.

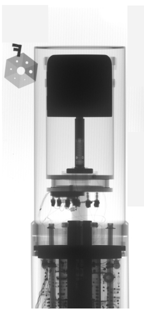
Detection efficiency: calculated with Monte Carlo simulation (Geant4):

- Calculated detection efficiency: 0.922 (2).

Photon spectrometry

HPGe detector

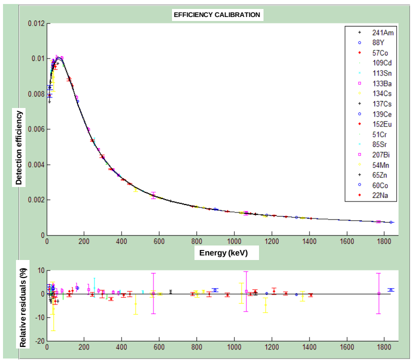
- N type - Volume: 93 cm^3
- Full-energy peak (FEP) efficiency calibration using standard sources from LNHB.
- Relative combined uncertainties:
  - ✓ 1-2 % (30-120 keV),
  - ✓ 0.6 % (120-1500 keV),
  - ✓ 1 % (> 1500 keV).



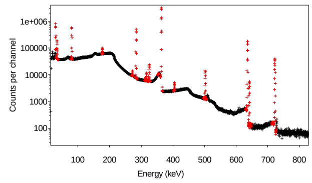
Absolute photon emission intensities:

$$I_i = \frac{n_i \cdot \prod C_{ij}}{\varepsilon_i \cdot A}$$

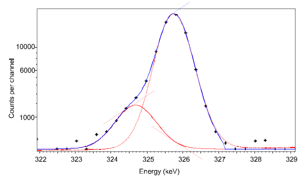
n_i: count rate in the peak corresponding to energy E_i,
ε_i: detector FEP efficiency for E_i, in the calibration geometrical arrangement,
A: source activity (*Bq*),
$C_{i,j}$: correction factors.



FEP efficiency calibration for point source at 10 cm from the detector window



Spectrum obtained with I-131 point source



Processing of the 324-325-keV doublet with the COLEGRAM software

Results

The absolute emission intensities of 15 gamma-ray lines in the decay of I-131, and those of the two K X-ray lines of xenon were determined.

Moreover, for comparison purposes, the relative photon emission intensities of I-131 were calculated, using the 364.5-keV line as the reference (100%):

$$I_{iR} = \frac{\dfrac{n_i \prod C_{ij}}{\varepsilon_i \cdot A}}{\dfrac{n_M \prod C_{Mk}}{\varepsilon_M \cdot A}} \cdot 100 = \frac{n_i \prod C_{ij}}{n_M \prod C_{Mk}} \cdot \frac{\varepsilon_M}{\varepsilon_i} \cdot 100$$

The present results are generally in agreement, within the uncertainty limits, with the other published values, especially with the most recent X-ray ones of Chand *et al.* (1989) and the gamma-ray measurements of Meyer, (1990) and the uncertainties assessed for the present study are significantly lower.

Energy (keV)	Present work Relative intensities (%)	Present work Absolute intensities (%)	Previous works Meyer (1990) or Chand *et al.** (1989) (%)	Chisté (in Bé *et al.*, 2004) (%)
29.67 (Kα)	5.08 (8)	4.13 (6)	4.18 (12)*	4.39 (8)
33.84 (Kβ)	1.193 (19)	0.970 (14)	0.912 (25)*	1.021 (22)
80.19	3.189 (39)	2.593 (29)	2.60 (3)	2.607 (27)
85.90	0.0079 (9)	0.0053 (6)	0.00009 (5)	0.000089 (49)
177.21	0.3528 (45)	0.2868 (34)	0.263 (2)	0.2654 (32)
272.50	0.0715 (22)	0.0581 (17)	0.056 (1)	0.0572 (9)
284.31	7.66 (7)	6.227 (43)	6.01 (6)	6.06 (6)
318.09	0.1022 (24)	0.0830 (19)	0.079 (3)	0.0796 (15)
324.65	0.0343 (6)	0.02786 (48)	0.022 (4)	0.0218 (26)
325.79	0.3318 (35)	0.2697 (25)	0.249 (4)	0.267 (26)
358.40	0.0199 (25)	0.0162 (20)	0.0091 (2)	0.0098 (22)
364.49	100.0 (8)	81.3 (5)	80.6 (16)	81.2 (8)
404.81	0.0695 (23)	0.0565 (18)	0.056 (2)	0.0551 (13)
503.00	0.4341 (48)	0.3529 (35)	0.358 (7)	0.3589 (43)
636.99	8.77 (7)	7.132 (48)	7.21 (9)	7.26 (8)
642.72	0.2685 (28)	0.2183 (20)	0.218 (4)	0.2193 (28)
722.91	2.208 (19)	1.795 (13)	1.79 (4)	1.796 (20)