Conversion electron emission probabilities for efficiency calibration of electron detectors and spectrometers

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Introduction

The low energy efficiency calibration of electron detectors is performed with good calibration standards in many online and offline facilities for beta and conversion electron spectroscopy. Long lived radioisotopes with distinct and strong conversion lines are preferred for this purpose. The electron capture decays of ^{169}Yb (32.018 d) and ^{153}Gd (240.4 d) and the beta decay of the isomer ^{177m}Lu (160.4 d) are very useful for this purpose in experimental nuclear spectroscopy. These sources provide intense and well-established low energy gamma rays for the efficiency calibration of solid-state detectors in the gamma energy range of 10 to 400 keV and conversion lines for electron detectors and spectrometers in the energy range of 10 to 350 keV, where not many calibration points exist.

We have used our [1] well-calibrated, high transmission Mini-Orange Spectrometer to precisely determine the conversion electron intensities of low energy transitions in the *ε*–decays (electron capture) of ^{153}Gd to ^{153}Eu, ^{169}Yb to ^{169}Tm, and the β-decay of ^{177m}Lu to ^{177}Hf, for use as efficiency calibration standards for electron detectors and spectrometers. The spectrometer consists of orange-type configurations of permanent magnets around a central absorber coupled with an Si(Li) solid-state detector. It serves as a compact and versatile multi-channel spectrometer for conversion electrons. The spectrometer is capable of separating electrons from dominating backgrounds of α, β+, γ and δ radiation with good filtering properties over broad and adjustable energy ranges (10 keV to 1.0 MeV). Absolute detection efficiencies are about 7% at lower energies and more than 3% at the higher energies. They allow decay studies with even weak sources (nCi) of short-lived activities.

Experiment.

For the conversion electron measurements, we employed the mini-orange spectrometer [1] comprising of i) a windowless Si(Li) detector (surface area =78 mm^2, sensitive depth =5.3 mm, FWHM = 1 keV at 115 keV and 2.3 keV at 624.5 keV), and ii) a mini-orange filter having nine thin wedge-shaped permanent magnets fixed in an orange array in a circular brass frame of 16.2 cm diameter, and a central absorber made of lead to prevent direct exposure of the Si(Li) to photons from the source. A clean vacuum of about 10^{-6} mbar was maintained. Suitable transmission curves from which transmission values may be interpolated for a given energy and source-magnet-detector geometry were obtained using various geometries.

To optimize the medium energy region, ^{131}Ba and ^{75}As radioactive sources were used. Conversion electrons were recorded for a minimum period of 10^5 seconds. Several runs were taken with sources of different thicknesses. The count rates for all measurements were maintained between 500-1000 cps. The conversion electron spectra were analyzed using the computer codes FIT [2] and GAMMAVISION [3] for precise energies and areas under the conversion electron peaks.

A well calibrated coaxial HPGe detector (GMX-10180p; volume =60 cc; FWHM =1.8 keV at 1.33 MeV, 665 eV at 5.9 keV) was used for the measurements of gamma ray energy and relative intensity of each of the radioisotopes. These values were used to obtain the gamma ray emission probabilities.

Table 1a: Conversion line intensities per 100 decays for transitions in ^{169}Tm

Gamma transition energy E_γ (keV)	Conv-ersion shell	Conversion electron energy E_{CE} (keV)	Conversion electron intensity per 100 decays p_{ce}
109.79	K	50.4	31.5(13)
118.8	K	58.8	1.20(7)
130.52	K	71.1	5.75(29)
93.62	L	84.2	1.12(7)
93.62	M	91.8	0.36(2)
109.79	L	100.3	5.08(25)
118.18	L	108.7	2.34(14)
177.21	K	117.8	9.53(38)
130.52	L	121.1	4.88(24)
130.52	M	128.7	1.40(8)
197.95	K	138.6	12.9(5)
177.21	L	167.7	1.81(11)
177.21	M	175.4	0.51(3)
197.95	L	188.5	2.18(13)
261.09	K	201.7	0.45(3)
307.77	K	248.3	0.45(3)
261.09	L	251.6	3.48 3
307.77	L	298.3	0.14(1)

Table 1b: Conversion line intensities per 100 decays for transitions in ^{153}Eu

Gamma transition energy E_γ (keV)	Conv-ersion shell	Conversion electron energy E_{CE} (keV)	Conversion electron intensity per 100 decays p_{ce}
19.80	L	12.3	2.74(27)
69.67	K	21.1	10.7(6)
75.39	K	26.9	0.038(4)
83.37	K	34.9	0.50(4)
89.48	K	41.0	0.131(11)
97.43	K	48.9	7.7(4)
103.18	K	54.7	21.4(10)
69.67	L	62.1	1.18(9)
69.67	M	68.2	0.163(11)
83.37	L	75.8	0.159(12)
89.48	L	81.9	0.015(1)
97.43	L	89.9	0.027(2)
103.18	L	95.6	3.30(23)
103.18	M	101.7	1.51(11)
172.86	K	124.3	0.0186(15)

Table 1c: Conversion line intensities per 100 decays for transitions in ^{177}Hf

Gamma transition energy E_γ (keV)	Conv-ersion shell	Conversion electron energy E_{CE} (keV)	Conversion electron intensity per 100 decays p_{ce}
105.36	K	40.0	31.7(21)
112.95	K	47.6	18.1(10)
128.50	K	63.1	23.6(12)
136.72	K	71.4	1.13(16)
145.77	K	80.4	0.90(17)
153.28	K	87.9	15.0(9)
228.48	K	163.1	4.00(20)
327.68	K	262.3	0.85(6)
378.50	K	313.1	0.73(4)
418.54	K	353.2	0.50(2)

Results

The relative conversion electron intensities were corrected for the transmission of the spectrometer. These intensities were converted into conversion electron probabilities (per 100 decays) by using the experimental gamma ray intensities measured with our HPGe detector system. The value of the multiplicative factor for obtaining the gamma ray emission probability (p_γ) and a standard conversion coefficient in the same decay, were taken from the adopted values given in the ENSDF database. The conversion electron intensities per 100 decays given in Table 1a-1c are arranged in increasing order of conversion electron energies from 12 keV to 350 keV. Individual conversion lines are designated with the corresponding gamma transition energy in keV.

As these measurements are relatively of high precision, and are well spaced in the said energy range, this conversion electron intensity data would be of great use for the calibration of Si(Li) detectors and associated electron spectrometers.

References

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