Evaluation of Photon Emission Probability Data for ^{56}Co $\varepsilon+\beta^+$ Decay

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The radionuclide ^{56}Co is potentially very useful for intensity calibration of Ge detectors. It is readily produced via the ^{56}Fe(p,n) reaction, its half-life of 77.24 d is conveniently long and it provides a number of relatively strong γ rays with energies up to ~3500 keV. The only practical detector-calibration radionuclide which has transitions of equal or greater energy is ^{66}Ga, for which the half-life is only 9.49 h. With the advent of several precise intensity measurements subsequent to the last evaluation of intensity data for ^{56}Co decay, it became clear that a new evaluation of the experimental intensity data was needed.

All data published in 31 papers between 1965 and 2002 for 46 transitions with energies between 263 keV and 3612 keV were evaluated. The evaluation of these data was complicated by two factors. Firstly, data sets for many of the transitions were discrepant. Of the approximately 770 data points, 87 were identified as statistical outliers based on the Chauvenet criterion. This seems to be an exceptionally large fraction. Secondly, some authors had used Ge detector efficiency curves which were inadequate at the higher energies. This problem was limited to transitions for which E_γ>3000 keV and it was solved by considering only the data from the eight experiments in which the authors had measured (not extrapolated) their detector efficiency curves.

Various approaches for dealing with discrepant data sets have been proposed in the literature. We analyzed the ^{56}Co data using three of the available methods. One method is the limitation of relative statistical weights (LRSW) proposed by Zijp [1]. In this method, a set of data is identified as 'discrepant' if its reduced χ^2 value exceeds the critical χ^2 value for the relevant number of data points. For such data sets, any datum whose relative statistical weight exceeds 50% will have its uncertainty increased until that is no longer true. If the weighted mean then overlaps the unweighted mean, the weighted mean will be adopted. The uncertainty used is usually the internal uncertainty; however, it will be expanded to include the most precise datum, when relevant, and the external uncertainty will be used instead if the internal uncertainty is less than that for the most precise datum. Otherwise, the unweighted mean would be recommended. However, the latter does not seem to be a particularly useful number since it could so readily be skewed by the least reliable data; in no case was it adopted in this evaluation. Two alternative methods, designed specifically to handle discrepant data sets, are the Normalized Residuals [2] and the Rajeval [3] techniques. Both employ iterative procedures, but use different prescriptions for identifying and then adjusting the uncertainties for the data points considered discrepant. Another logical approach might be to apply the LRSW method following the removal from the data set of all statistical outliers.

The results of all the above analyses of the 18 discrepant data sets were compared; for these, the recommended intensities were taken from the LRSW method applied to data sets retaining statistical outliers (4 cases), the Normalized Residuals method (10 cases) or the mean of the Normalized Residuals and the Rajeval methods, along with the larger of the two uncertainties (4 cases). For non-discrepant data sets, the weighted mean was adopted (27 cases).

The ^{56}Co decay scheme is well established and it was normalized assuming no $\varepsilon+\beta^+$ feeding to the ^{56}Fe ground state (ΔJ=4 transition) and a conversion coefficient of 3.03x10^{-4} for the 847-keV transition in order to deduce I_γ per decay.

The values recommended for the strongest lines are given in table 1. These data will be included in the International Atomic Energy Agency Coordinated Research Programme document *Update of X- and Gamma-ray Decay Data Standards for Detector Calibration and Other Applications*, and the analysis for all transitions along with relevant atomic data are available from the Decay Data Evaluation Project: http://www.nucleide.org/DDEP_WG/DDEPdata.htm.

Table 1. Recommended values for the photon intensity relative to I(847γ)=100, the reduced χ^2 for each data set and the absolute photon emission probability for ^{56}Co decay. Transition energies are adopted from the evaluation by Helmer and van der Leun [4]. Only transitions whose intensity exceeds ~1% of I(847γ) are included here.

Energy (keV)	Relative I_γ	Reduced χ^2	I_γ per decay
846.7638 (19)	100		0.999399 (23)
977.363 (4)	1.423 (7)	2.7	0.01422 (7)
1037.8333 (24)	14.04 (5)	4.5	0.1403 (5)
1175.0878 (22)	2.250 (9)	2.8	0.02249 (9)
1238.2736 (22)	66.45 (16)	1.8	0.6641 (16)
1360.196 (4)	4.283 (13)	0.9	0.04280 (13)
1771.327 (3)	15.46 (4)	1.3	0.1545 (4)
2015.176 (5)	3.019 (14)	2.5	0.03017 (14)
2034.752 (5)	7.746 (13)	1.7	0.07741 (13)
2598.438 (4)	16.97 (4)	1.3	0.1696 (4)
3009.559 (4)	1.039 (19)	7.5	0.01038 (19)
3201.930 (11)	3.205 (13)	1.6	0.03203 (13)
3253.402 (5)	7.87 (3)	1.1	0.0787 (3)
3272.978 (6)	1.856 (9)	1.1	0.01855 (9)
3451.119 (4)	0.943 (6)	1.2	0.00942 (6)

REFERENCES

[1] W. L. Zijp, Report ECN FYS/RASA-85/19 (1985).

[2] M.F. James, R.W. Mills, and D.R. Weaver, UKAEA Report AEA-RS-1082 (1991).

[3] M.U. Rajput and T.D. MacMahon, Nucl. Instrum. Meth. Phys. Res. A 312, 289 (1992).

[4] R.G. Helmer and C. van der Leun, Nucl. Instrum. Meth. Phys. Res. A 450, 35 (2000).