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Activity measurements and determination of gamma-ray emission intensities in the decay of ^{65}Zn ☆

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Abstract

An International EUROMET exercise, Action 721, was organized with the objective of obtaining more reliable decay data on the disintegration of ^{65}Zn. Nine laboratories participated, sending their results relating to activity measurements and 1115-keV gamma-ray emission intensity. Participants mainly used the $4\pi\beta$-γ coincidence method for the activity measurement, the resulting values and uncertainty budgets are described. New gamma-ray emission intensities were also measured in this exercise and, taking into account previously published values, the intensity of the 1115-keV gamma-ray emission has been determined to be 50.22(11)%.

Keywords: Radioactivity; ^{65}Zn; Gamma-ray intensities

1. Introduction

Over the previous 20 years, a number of laboratories have participated in SIR (BIPM) and results showed that the mass activity of ^{65}Zn as determined by gamma-ray spectrometry appeared to be about 2% less than that determined using $4\pi\beta$-γ coincidence counting (Michotte et al., 2006).

Activity determination by gamma-ray spectrometry is directly correlated to the intensity of the 1115-keV gamma emission and the associated uncertainty. Since gamma-ray spectrometry is one of the easiest and most common measurement techniques, there are strong practical reasons to reduce any differences between the activity values obtained by means of the various measurement methods.

A new international exercise (EUROMET 721) has been formulated to study and measure the gamma-ray emission intensities, with the aim of increasing the accuracy of the ^{65}Zn decay scheme data. Participants (Table 1) were requested to measure the activity and the X- and gamma-ray emission intensities of the solution provided by LNHB staff. After collection of all report forms, an arbitrary code number was allocated to each participating laboratory. All the results were compiled in a specific report in which full details can be found (Bé, 2005), and were compared with other previously published measurements to derive a new decay scheme.

2. Procedure

2.1. General description

Ampoules of ^{65}Zn were sent to the participants as well as a description of the previous available recommended decay scheme data (Helmer, 1999).

The first part of this exercise was dedicated to activity measurements, in which participants filled in a questionnaire that assisted in defining the main characteristics of their equipment, the method of measurement, the procedure and main correction factors, the results and associated uncertainties, etc.

The objective of the second part of the project was the determination of the X- and gamma-ray emission intensities, in which participants provided a description of their equipment, details of the main experimental procedures, method of peak analysis, and the results of their measurements of the X- and gamma-ray emissions.

☆This paper is dedicated to Richard G. Helmer in recognition of his significant contributions to the world of decay data evaluation, and his generous assistance and encouragement of colleagues in the field.

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Table 1
EUROMET 721: ^{65}Zn—list of participating laboratories

Laboratory	Address	People who carried out the measurements
NMIJ	National Institute of Metrology of Japan Tsukuba, Japan	Y. Hino, Y. Sato
PTB	Physikalish Technische Bundesanstalt Braunschweig, Germany	K. Kossert, R. Klein, M.K.H. Schneider, H. Schrader
CMI	Czech Metrological Institute Praha, Czech Republic	P. Dryak, J. Sochorovà
IRMM	Institute for Reference Material and Measurements Geel, Belgium	T. Altzitzoglou
IRD-LNMRI	Laboratorio Nacional de Metrologia das Radiações Ionizantes Rio de Janeiro, Brazil	A. Iwahara, M.A.L. da Silva, J.U. Delgado, C.J.Silva
NPL	National Physical Laboratory Teddington, UK	L. Johansson, S. Collins
KRISS	Korea Research Institute of Standards and Science Yusong, Taejon, South Korea	Jong-Man Lee, Kyung Beom Lee, T.S. Park
IFIN-HH	"Horia Hulubei" National Institute of Physics and Nuclear Engineering Bucharest, Romania	A. Luca, M. Sahagia, A.C. Razdolescu, E.L. Grigorescu
LNHB	Laboratoire National Henri Becquerel Gif-sur-Yvette, France	C. Bobin, J. Plagnard , M.C. Lépy, M.N. Amiot

2.2. Properties of the distributed solution

The primary solution was purchased from Cerca/LEA. Before sample preparation, purity tests were carried out by gamma-ray spectrometry (HPGe of total volume $\sim$100 cm^3). ^{60}Co impurity was detected with an activity ratio $A(^{60}Co)/A(^{65}Zn)$ equal to 4×10^{-5}, as confirmed by the participants and considered to be negligible.

A final activity of about 850 kBq/g, was obtained by dilution. About 30 g of 0.1 M HCl, 9.2932 g of the ^{65}Zn radioactive solution, and then 0.1 M HCl were mixed in a flask to give 74.5626 g total mass of solution. This preparative procedure (Iroulart and Branger, 2004) resulted in a dilution factor of 8.0233 and a final activity equal to 858.7 kBq/g (15/01/2004, 0 h UTC, adopted reference date).

Each ampoule was weighed empty, and 5 mL of the solution was added. Then, the ampoule was weighed again to determine the exact mass of solution. Fifteen ampoules were prepared and sealed in this manner, and homogeneity was checked by means of an ionization chamber—homogeneity factor was found to be around 1‰.

3. Activity measuring methods

Except for two participants, who individually used an ionization chamber and liquid scintillation counting method, all laboratories carried out the activity measurement by means of the $4\pi\beta$-γ coincidence method.

3.1. $4\pi\beta$-γ coincidence method

The sources were prepared on gold-coated Vyns films, except in one case where collodion films were preferred. Wetting agents (such as Ludox and Catanac) were added to the deposited drops and weighed using the pycnometer method. Then, the sources were dried in most cases under an infrared lamp; Participant 5 used an unusual freeze-drying method.

All laboratories used a gas-flow proportional counter in the beta channel, working at atmospheric pressure or under pressures from 0.1 to 0.9 MPa. The operating gas was pure methane or a mixture of 90% Ar and 10% CH_4.

One laboratory used a hyper-pure germanium (HPGe) detector in the gamma channel, while all of the others used a NaI(Tl) detector.

3.1.1. Uncertainty

All laboratories reported detailed uncertainty budgets. The main contributions came from the counting statistics, weighing, the decay scheme parameters and the extrapolation procedure, and the relative importance of these contributions greatly varied based on the analysis performed by each laboratory.

Uncertainty budgets for counting statistics varied from 0.05% to 0.32%, depending on the number of sources measured and on the count rate. Five laboratories claimed a value of 0.1% or less. Two laboratories obtained a value around 0.3%, in which one of them measured four sources with a count time of 10×100 s and the other measured twenty sources for 3000 s.

The uncertainty budget for the weighting parameter ranged from 0.05% to 0.10% for five participants, but was 0.01% and 0.19% for the two remaining laboratories. Three laboratories applied a correction based on taking the decay scheme parameters into account, and two others explicitly reported a budget of the order of 0.1%. Except for two participants, the extrapolation procedure made the largest contribution to the final uncertainty, varying from 0.01% to 0.34%.

3.2. Other methods

One laboratory used a well-type ionization chamber calibrated with ^{65}Zn solution contained in two glass