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Application of the sum-peak and coincidence spectrometer to the determination of the absolute efficiency (*)

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Résumé. — Nous montrons comment l'utilisation de deux détecteurs de Ge(Li) identiques, permet de tirer parti des pics d'addition pour déterminer l'efficacité absolue de détection des photocopies.

Abstract. — We point out that the use of two identical Ge(Li) detectors allows us to take advantage of the parasitic summing effect to determinate the full energy peak efficiency.

Normally, in γ spectra, we observe distributions due to the addition in the detector of pulses coming from gammas emitted in coincidence by the sample studied. Generally, this addition effect not only complicates the stripping of the spectra, but also impedes an accurate estimate of the transition intensities [1-2]. However, some authors did try to take advantage of this addition effect [3-5].

In previous publications [6-9], we have demonstrated that great improvements in the determination of the energy levels of radioisotopes by the sum-peak technique of coincidence counting have been achieved by the use of two identical Ge(Li) detectors. They are located on either side of the sample, and are associated with a coincidence unit. The aim of this work is to show that the determination of the absolute full energy peak efficiency (F.E.P.E.) is also possible using this technique.

Let us consider a nucleus having at least three excited levels, the deexcitation of which is sketched in figure 1. It is easy to show [1, 7-9] that the experimental intensities S_{ij} and S_{ijk} of the sum-peaks corresponding respectively to the simultaneous absorption of the gamma i and j and i, j and k are given by the following relations :

$$S_{ij} = \frac{I_i \cdot I_j}{I_{N_2}} \cdot \varepsilon_i \cdot \varepsilon_j \cdot N \cdot T \cdot W . \quad (1)$$

$$S_{ijk} = \frac{I_i \cdot I_j \cdot I_k}{I_{N_3} \cdot I_{N_2}} \cdot \varepsilon_i \cdot \varepsilon_j \cdot \varepsilon_k \cdot N \cdot T \cdot W , \quad (2)$$

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Fig. 1. — Example of a deexcitation mode allowing the determination of the F.E.P.E.

where : I_i , I_j and I_k are the intensities of γ_i , γ_j and γ_k respectively ; ε_i , ε_j and ε_k are the F.E.P.E. at the energies E_i , E_j and E_k ; I_{N_2} and I_{N_3} the intensities of the population of the levels N_2 and N_3 (Fig. 1) ; N is the activity of the source ; T the duration of the experiment and W a coefficient of angular distribution.

The ratio of (2) to (1) gives the F.E.P.E. at energy E_k :

$$\varepsilon_k = \frac{S_{ijk}}{S_{ij}} \cdot \frac{I_{N_3}}{I_k} . \quad (3)$$

As an application of the method we have measured, during the excitation of ^{110}Cd [10] (Fig. 2) the F.E.P.E. at 937.5 keV of two identical $44.4 \phi \times 47.5 \text{ mm}^2$ single-ended Ge(Li) detectors grown from the same Ge ingot. The detectors had an active volume of 70.5 cm^3 and an energy resolution of 2.2 keV at 1.33 MeV. The distance between the detector cases and the source was 10.0 cm. Relation (3) allows us to write :

$$\xi_{(937.5 \text{ keV})} = \frac{S_{2479.9 \text{ keV}}}{S_{1542.4 \text{ keV}}} \cdot \frac{I_{N(1542.4 \text{ keV})}}{I_{\gamma(937.5 \text{ keV})}} = 0.0429 \pm 0.0012 .$$

Measurements of peak areas of 2479.9 (937.5 + 884.7 + 657.7 keV) and 1542.4 keV (657.7 + 884.7 keV) were performed sixty six times (during 800 hours) with a 8192 channel analyser (Hewlett-Packard 5401/B) during our study of the sum-peak and coincidence spectrum of $^{110}\text{Ag}^{m+s}$ [8], while $I_{N(1542.4 \text{ keV})}$ and $I_{\gamma(937.5 \text{ keV})}$ are the intensities, due to the results of Meyer's work [11, 12].

The extensive use of semi-conductor detectors in γ -spectrometry has led many authors to propose original experimental or theoretical methods for the absolute efficiency determination. Waibel *et al.* [13] have classified the experimental methods in four categories :

1) the simplest method needs calibrated γ -ray sources. The experimental photopeak efficiency of detection for a given γ -ray is evaluated [14] from measured data on the basis of the equation (4)

$$\varepsilon = \frac{N}{A \cdot t \cdot I} , \quad (4)$$

Fig. 2. — Partial level scheme of ^{110}Cd .

where : N is the number of detected pulses in the photopeak area,
 A is the disintegration rate of the γ -ray source,
 t is the counting time, and
 I is the absolute intensity of the relevant γ -emission ;

- 2) for high γ -ray energies, well defined γ -ray sources produced by nuclear reactions are used. In this case, it is absolutely necessary to know the cross sections and the emission probabilities ;
- 3) the coincidence method allows us to determine simultaneously the efficiency of the detector and the source strength ;
- 4) above 1.022 MeV, relative efficiency determination is possible with a pair spectrometer, but the absolute efficiency determination requires a calibrated source.

The accuracy of Ge(Li) efficiency curves over the range 0.1-3.0 MeV obtained with these methods is generally contained between 0.5 and 5 % [15-18].

Several authors have proposed semi-empirical formulae and analytical functions to represent the F.E.P.E. curves of the Ge(Li) detectors [19-21]. The validity of these relations has been tested successfully for a great range of detectors, the accuracy being related to a precise knowledge of the detector dimensions.

In addition to the fact that the suggested technique i.e. using the parasitic summing effect positively is easy to use when it is enlarged to the F.E.P.E. determination of one detector used in the single mode, we remark that in the chosen example the uncertainty is lower than 3 % and consequently comparable to the previous methods.

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