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Dependence of self-absorption on thickness for thin and thick alpha-particle sources of UO_2

M. Jurado Vargas[a,*], A. Fernández Timón[b]

[a]Departamento de Física, Universidad de Extremadura, 06071, Badajoz, Spain
[b]Universidad Rey Juan Carlos, 28933, Móstoles-Madrid, Spain

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Abstract

Activity measurements of alpha-particle sources with significant thicknesses require corrections for the self-absorption of alpha particles in the source. The dependence of the self-absorption coefficient on source mass varies according to the chemical composition of the substrate, and is often obtained empirically by measuring a great number of sources with known activity and different thicknesses. In the present work, we use Monte Carlo simulation for this task, applying the computer code SRIM, developed to simulate the transport of ions in matter, to the determination of the self-absorption coefficients for alpha-particle sources measured in detectors with a 2π counting geometry. In particular, the coefficients were calculated for sources of uranium dioxide containing ^{235}U, with a wide range of source thicknesses: from 1.0 to 10 mg/cm^2 (thin sources, with thicknesses smaller than the range of alpha particles) and from 11 to 30 mg/cm^2 (to cover self-absorption in thick sources). The behaviour obtained for the dependence of self-absorption on thickness for these two thickness regions was compared with a simple theoretical model. The simulation results were in good agreement with the model, although there were some discrepancies for thin sources, which can be explained by taking into consideration the scattering of alpha particles in the source. The present work shows the utility of using the Monte Carlo code SRIM to evaluate the self-absorption corrections needed in the measurement of alpha-particle sources.

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1. Introduction

Although the theoretical efficiency in detection systems with 2π counting geometry is 50%, in many cases the real counting rate is not one-half of

*Corresponding author. Tel.: +34 924 289 300; fax: +34 924 289 651.
E-mail address: mjv@unex.es (M. Jurado Vargas).

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the source activity, because some of the alpha particles initially emitted up towards the detector are absorbed in the source, while others initially emitted down towards the source backing are backscattered. The backscattering effect can be greatly minimized using backings with elements of low atomic number, but self-absorption corrections to the counting rate are always needed when the source contains long half-life nuclides, with self-absorption in the source being significant. Self-absorption corrections are also especially important in the technique of gross alpha-particle detection, which constitutes a simple and robust method often used for screening radioactivity in waters. Using this technique, sources usually have great thicknesses because the preparation commonly involves direct evaporation of water (measuring the residue) or coprecipitation.

The self-absorption coefficient depends on the composition and thickness of the source material, and on the energy of the alpha particles. Although some theoretical treatments have been developed to determine the self-absorption corrections [1,2], these are often found empirically by using a great number of sources of the same material with a wide range of thicknesses. The discrete experimental values of the self-absorption coefficient must then be fitted by some function in order to obtain the self-absorption correction for a source of any given thickness. Several workers [1–6] have applied different functional forms that depend on such factors as the source's non-uniformity, the thickness of the sample (thin or thick sources), the existence of absorbers between sample and detector, edge effects in the source and detector, etc.

Self-absorption can also be analysed by adopting Monte Carlo methods to simulate the behaviour of the alpha particles in the source. There has been recent work that simulates the interaction of alpha particles in matter in order to calculate backscattering and self-absorption corrections to the counting rate in a 2π detection geometry, but only for the particular case of very thin sources (thicknesses much smaller than the alpha-particle ranges). Examples are the work of Ferrero et al. [7] and our studies for weightless sources [8,9] and for very thin sources by analyzing conjointly the two corrections to the counting rate (backscattering and self-absorption corrections) [10].

The aim of the present work is to extend the application of the Monte Carlo method to a wider range of thicknesses, including both thin and thick sources, without considering the backscattering correction in the backing, so that only the self-absorption corrections to the counting rate will be studied. In particular, we simulated alpha-particle sources of $^{235}UO_2$ with a wide range of source thicknesses that included thin (from 1.0 to 10 mg/cm^2) and thick sources (from 11 to 30 mg/cm^2). The behaviour of the self-absorption coefficient with varying sample thickness was compared with a simple theoretical model used for both types of source.

2. Theoretical approximations

We consider here a simplified model to explain the self-absorption of alpha particles in a 2π counting geometry, as shown in Fig. 1. The sample containing the alpha-particle emitter is assumed to have a thickness d and an infinite diameter, and the alpha particles have a range R in the source. We distinguish two intervals of sample thicknesses. A sample is defined as thin when alpha particles emitted normally to the source plane from any depth in the sample can be detected ($d < R$). However, when $d > R$ (defined as a thick sample), alpha particles emitted from depths greater than R

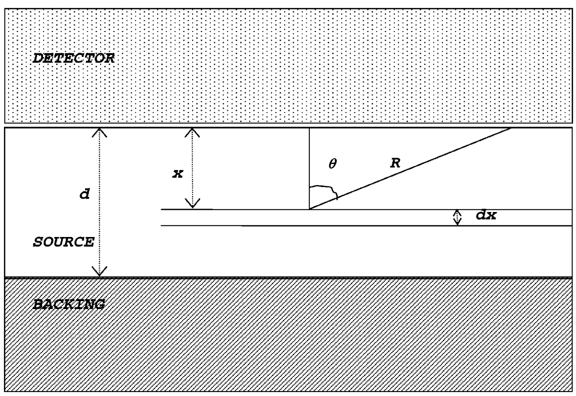

Fig. 1. Angles and distances considered in explaining self-absorption in the source.