Revista CENIC Ciencias Químicas, 17, 3, 1986

AN ANALYTICAL EXPRESSION FOR MÖSSBAUER ABSORPTION LINE AREA IN LORENTZIAN ENVIRONMENTAL BROADENING: A SIMPLE DERIVATION

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Received: 13th april, 1984

ABSTRACT. An analytical expression for Mössbauer Absorption line area is obtained. This expression may be used for explaining Mössbauer spectra with broadened lines. It is also presented a comparison with other known expressions that are exposed in the references.

RESUMEN. Se obtiene una expresión analítica para el área de la línea de absorción Mössbauer. Esta expresión puede ser empleada en la interpretación de espectros Mössbauer con líneas ensanchadas. Se presenta además una comparación con otras expresiones citadas en las referencias.

INTRODUCTION

The area is an important parameter of the Mössbauer absorption line. Through this area it is possible to obtain the relative population of resonant nuclei at different Mössbauer sites in the studied sample.

The line area not only depends on the number of resonant nuclei in the correspondent Mössbauer site, but it also depends on the cross section for resonant absorption by these nuclei or the so-called absorbent linewidth (Γ_a. The value "Γ_a" is generally larger than the natural linewidth (Γ_{nat}) given by the decay constant of the excited nuclear level. This broadening can be caused by effects of temporal or spatial inhomogeneities of internal fields on the resonant nucleus.

An analytical expression for the Mössbauer absorption line area, when $\Gamma_a = \Gamma_{nat}$, was reported by Bykov and Hien.[1] In the most common case, where $\Gamma_a \neq \Gamma_{nat}$, Lang[2] expressed the line area as an infinite sum, while Mrup and Both[3] used an approximated formula for thin absorbers.

The attainment of an analytical expression for the line area as a function of parameters "Γ_a" and "t" (specific absorber thickness) is relatively easy if it is followed the formalism, which was used by Williams and Brooks[4] in the derivation of the Bykov and Hien[1] formula.

The objective of this paper is to obtain the mentioned analytical expression.

THEORY

It is known that the Mössbauer Absorption Line Area is independent of the emission line shape when the background is substracted.[1,2] However, in the following treatment it is assumed by simplicity that the Mössbauer emission line shape is Lorentzian. Neglecting the resonant absorption in the source, the energy distribution of the recoilless radiation emitted from a source moving with velocity v will be expressed as:

$$I_s(S) = \frac{f_s\Gamma_s / 2\Pi)}{(E + S - E_s)^2 + (1/2\ \Gamma_s)^2} \tag{1}$$

Where:

$S = E_s(V/C)$,
E_s : energy corresponding to source line,
C : velocity of light,
Γ_s : emission linewidth,
f_s : Recoil-free fraction of the emitted radiation

When the absorber nucleus has an energy dependent cross section for resonant absorption given by:

$$\sigma(E) = \sigma_0 \frac{\Gamma_a \Gamma_{nat}}{(E - E_s)^2 + (1/2\ \Gamma_a)^2} \tag{2}$$

Where:

$$\sigma_0 = 2\Pi\ \lambda^2 \frac{2I_e + 1}{2I_g + 1} \cdot \frac{1}{1 + \alpha},$$

α : internal conversion coefficient,
λ : reduced wavelength of gamma radiation
$I_e I_g$: spin of the nucleus in the excited and ground state