THE APPLICATION OF SELECTIVE EXCITATION DOUBLE MÖSSBAUER TO TIME-DEPENDENT EFFECTS IN BIOLOGICAL MATERIALS

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This paper is concerned with the development and application of selective excitation double Mössbauer (SEDM) techniques to the study of time-dependent hyperfine interactions in biological systems. The Mössbauer effect (ME) is the recoilless emission and absorption of nuclear resonant radiation. Usually these are γ-rays of energy from 10 to 100 keV. Under special and quite well understood conditions the γ-ray is emitted and absorbed without loss of energy and is highly monochromatic (line width for ^{57}Fe $\sim 10^{-9}$ eV). All Mössbauer experiments are based on the utilization of this extremely well-defined energy to measure small energy differences. It is a convenient coincidence that iron, important biologically, also has the most suitable isotope, ^{57}Fe, for Mössbauer spectroscopy. This coincidence allows us to study heme proteins, iron sulfur proteins, iron transport and storage proteins, and other important systems.

The spectra of biological materials very often are quite complex and difficult to interpret by the standard Mössbauer techniques. SEDM will help us resolve some of the complex spectra and allow us to obtain more specific information not available from the usual ME investigations. The SEDM apparatus requires two Doppler modulators. The first one drives a single-line Mössbauer source at a constant velocity, thereby inducing a transition of the nuclei in the scatterer to a predetermined excited substate. The other drive moves a single-line absorber and is used in the usual transmission geometry to analyze the scattered radiation. In this way we measure the nuclear resonant differential scattering cross-section of a material. The other Mössbauer techniques usually measure the absorption cross-section.

We have used SEDM to obtain new information on several inorganic materials

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(1–4). We have also developed theoretical expressions to calculate the effect of electronic relaxation on the SEDM spectra. In this paper we will present the results of a SEDM investigation of such processes in ferrichrome A (5).

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ON MAGNETICALLY INDUCED TEMPERATURE JUMPS

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Any generator of an alternating magnetic field also produces an alternating electric field. These fields may interact directly with ionic solutions or via (ferro-electric and/or -magnetic) mediators. The (local) energy density then has four contributing terms:

$$ {}_xQ'_a = {}_xQ'_{H,} + {}_xQ'_{E,L} + {}_xQ'_{H,M} + {}_xQ'_{E,M}. \qquad (1) $$

The various symbols in this equation—as well as in all later equations—are defined in the Glossary of Symbols (Table I). The subscript before Q refers to the x-axis, the direction of the propagation of the field. Fig. 1 below describes the simplified model used and defines the directions of the electric and magnetic field vectors.

At the boundary plane the magnetic field strength is defined by:

$$ H_Z(0,t) = H_0 \sin \omega t. \qquad (2) $$

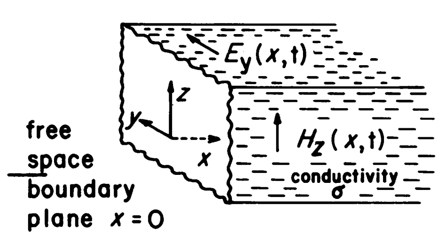

Figure 1 Set of definitions of an electromagnetic wave, propagating in the x-direction, and entering a "slab" at $x = 0$.