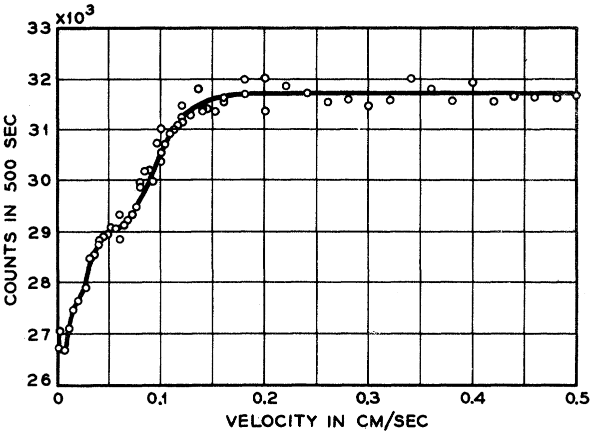

FIG. 2. The hyperfine structure of $Fe^{57}$ in $n$-type silicon obtained with a stainless steel absorber.

for iron in a normal iron site.[5] The silicon source exhibits sufficiently weak hyperfine coupling so that samples of this type may be useful as unsplit sources in the investigation of other iron-bearing materials. They have the advantage over sources made by incorporating $Co^{57}$ into stainless steel or potassium ferrocyanide that self-absorption in the source is negligible due to the absence of stable $Fe^{57}$.

The author is indebted to W. L. Brown, V. Jaccarino, and W. E. Blumberg for discussions and suggestions during the course of this work; to K. M. Olsen for the high-purity iron, nickel, and stainless steel foils used in these investigations; and to H. C. Montgomery, G. Feher, and J. Eisinger for the loan of numerous pieces of equipment.

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# RECOILLESS RAYLEIGH SCATTERING IN SOLIDS

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Using the Mössbauer effect, photon sources and analyzers extremely selective in energy are now available. We study here with such an analyzer the recoilless Rayleigh scattering by atoms in solids.

This effect is related to the x-ray diffraction by crystals as follows. The interference at the exact Bragg angles occurs when the scattering is elastic with respect to the lattice as a whole, that is, without any phonon exchange. Debye and Waller have calculated the reduction in intensity of x rays scattered at the Bragg angles in a solid at temperature $T$,[1]

$$\varphi_T = \exp\left\{-\frac{3}{2}\frac{E_R}{k\theta}\left[\frac{1}{4}+\frac{1}{x}\int_0^x \frac{u\,du}{e^u-1}\right]\right\}, \qquad (1)$$

where $x = T/\theta$, $\theta$ is the Debye temperature, and $E_R = (E^2/Mc^2)(1-\cos\theta)$ is the recoil energy given to the free atom by a photon of energy $E$ scattered at the angle $\theta$.

In the present work, where we detect the elastic scattering directly by an energy selection instead of analyzing a diffraction pattern, the factor $\varphi_T$ is the relative number of photons scattered without energy change. It is clearly the same factor which gives the proportion of recoilless $\gamma$ rays in the Mössbauer effect[2]; in that case $E_R = E^2/2Mc^2$ in Eq. (1).

In order to measure the factor $\varphi_T$, we have studied the Rayleigh scattering for several materials: Pt, Al, graphite, and paraffin. The 23.8-kev photons emitted by $Sn^{119*}$ were scattered at 50°± 5° and absorbed by a $Sn^{119}$ foil 40 mg cm$^{-2}$ thick (almost completely black for the recoilless photons[3]) (Fig. 1). The scatterers' thicknesses were such that the transmission of the $\gamma$ rays was of the order of 10%.

The Rayleigh-scattered photons are accompanied by inelastically scattered photons (Raman, Compton), considerably shifted in energy, so that the selective absorption in $Sn^{119}$ occurs only

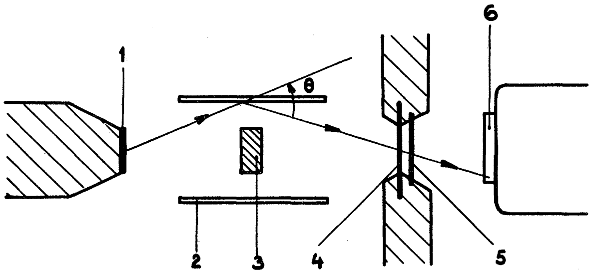

FIG. 1. (1) $Sn^{119*}$ source; (2) scatterer; (3) bismuth stopper; (4) 40 mg $cm^{-2}$ $Sn^{119}$ foil (71.5 % $Sn^{119}$); (5) 62 mg $cm^{-2}$ Pd foil absorbing Sn x rays; (6) 1.5 mm NaI(Tl) scintillator and photomultiplier.

for a fraction $\alpha$ of all the scattering processes; $\alpha$ is extracted from the form factors given by Compton and Allison.[4]

We have measured the relative decrease $\Delta$ of counting rate between room temperature $T_1 = 300°K$ and $T_2 = 80°K$. The recoilless scattering proportion at $T_2$ is approximately

$$\varphi_{T_2} = \frac{1}{\alpha}\,\frac{\Delta - \epsilon}{f_2 - \epsilon},$$

where $f_2$ is the ratio of recoilless emission of the $Sn^{119*}$ source and $\epsilon$ is its self-absorption at $T_2$. Here $f_2 = 0.32 \pm 0.015$ and $\epsilon = 0.05 \pm 0.01$. We neglect the small recoilless emission at 300°K which introduces a negligible correction for $\varphi_{T_2}$.

The results are given in Table I. The agreement between the calculated and experimental values of $\varphi$ is reasonably good, especially when we notice that the Debye temperatures are deduced from specific heat measurements rather than from x-ray diffraction.

Table I. Experimental and calculated values of $\varphi_{T_2}$.

| | $1/\alpha$ | $\Delta$ | $\varphi_{T_2}$ | $\varphi_{calc}$ |
|---|---|---|---|---|
| Pt | 1.05 | 0.27 ± 0.03 | 0.72 ± 0.09 | 0.80 |
| Al | 2.15 | 0.19 ± 0.016 | 0.92 ± 0.09 | 0.62 |
| C | 4.13 | 0.10 ± 0.01 | 0.79 ± 0.09 | 0.68 |
| $CH_2$ | 5.30 | 0.020 ± 0.01 | 0 | |

We have also, using a thin $Sn^{119}$ foil as a scatterer, observed at low temperature the resonant Mössbauer scattering.[5]

This method extends the range of solids which can be studied by means of the Mössbauer effect or by x-ray diffraction.

It is a pleasure to acknowledge interesting discussions with Dr. Abragam, Dr. Cotton, and Dr. Jacrot.

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# STUDY OF THE INTERMEDIATE STATE IN SUPERCONDUCTORS USING CERIUM PHOSPHATE GLASS

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Alers[1] has recently used the magneto-optic Faraday rotation in some cerous nitrate-glycerol solutions to observe the intermediate state in a superconducting lead alloy. This technique, like the bismuth probe[2] and the superconducting[3,4] or ferromagnetic[5] powder methods, makes use of the diamagnetism of the superconducting state to investigate the topography of the superconducting and normal domains at the surface of a specimen. In all these methods, it is assumed that the local magnetic field distribution and variations at the surface reflect the amount of normal and superconducting material in the specimen itself. More recently, Alers[6] has reported large Faraday rotations in some paramagnetic glasses containing cerium meta-phosphate suggesting their use in studying the structure of the intermediate state in superconductors.

Utilizing this Faraday effect in similar glass prepared by A. Pincus and R. H. Pry of this laboratory, we have obtained some preliminary results on resolving the intermediate state in various superconducting metals. Included in these early studies was the effect of different