SHAPE OF THE RESONANCE ABSORPTION SPECTRA OF 23.8 keV γ RAYS FROM Sn^{119m} *IN TIN OXIDE AND METALLIC WHITE TIN*

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The shape of the resonance absorption spectrum of the 23.8-keV γ rays of Sn^{119m} in tin oxide and metallic white tin was studied using a Mg_2Sn^{119m} source and a resonance counter. It was shown that the absorption spectrum of SnO_2 is a doublet with a splitting $\Delta = 0.50 \pm 0.02$ mm/sec; its magnitude is independent of temperature. In metallic tin the observed spectrum is a broadened single line whose width decreases with heating. If we assume the spectrum of β-Sn to consist of two lines having the natural width, such behavior can be explained by a change in the splitting Δ from 0.32 to 0.25 mm/sec when the temperature is raised from liquid nitrogen to room temperature.

INVESTIGATION of the resonance absorption of the 23.8-keV γ rays of Sn^{119} in metallic tin (β-Sn) and tin oxide (SnO_2) has shown that the absorption line is broadened in both cases.[1,2] Measurements on single crystal samples[3,4] permitted the conclusion that the broadening in the case of β-Sn is caused entirely by quadrupole interaction, while the cause of the broadening of the spectrum of SnO_2 was not definitely established.

From a study of the dependence of absorption spectrum shape on temperature,[2] the conclusion was drawn that in the case of SnO_2 the spectrum is a single Lorentzian line, whose width is considerably larger (by 0.7 mm/sec) than the value determined from the lifetime of the 23.8-keV level (where we mean the directly measured spectrum, whose width is the sum of the emission and absorption line widths). Later it was shown[4] by measurements on single crystals that the SnO_2 spectrum has a doublet structure, but the splitting found ($\Delta = 0.22$ mm/sec) could only partially explain the broadening of the spectrum.

In addition to interest in a possibly unknown cause of broadening, the problem of the shape of the γ ray absorption spectrum in tin oxide is interesting also because this compound, having a high probability for the effect, is used most frequently as the source for studies of the Mössbauer effect in Sn^{119}, so that precise knowledge of its emission spectrum is necessary for treating the results of measurements.

In the present work we used a Sn^{119m} source prepared from magnesium stannide, Mg_2Sn, having a single unbroadened emission line,[5] and a resonance detector based on this same compound,[6] hoping by using the increased resolving power because of resonance detection to obtain more exact information about spectrum shapes for the materials studied. The smallest line width of the resonance spectrum using standard detection techniques is 2Γ, (where Γ is the width of the excited level of the nucleus) while with the resonance counter the width is 1.47 Γ, i.e., about 0.2 mm/sec narrower.

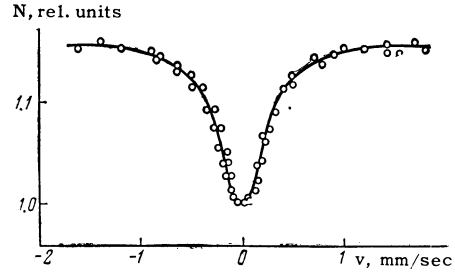

FIG. 1. Absorption spectrum for 8.9 mg/cm² Mg_2Sn absorber at 293°K. The abscissa is the absorber velocity, the ordinate the intensity of flux of γ rays in arbitrary units.

A detailed study of the "instrumental" line shape, using Mg_2Sn absorbers of different thicknesses, showed that the single absorption line is well approximated by a Lorentz curve over the whole range studied (the absorber thickness was varied so that the drop in counts of resonant γ rays at the absorption maximum varied from 8 to 90%). For illustration, Fig. 1 shows the absorption spectrum of Mg_2Sn measured using the resonance detector.

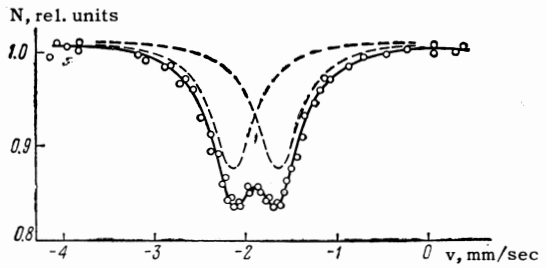

FIG. 2. Absorption spectrum for 4.42 mg/cm² SnO_2 absorber at 289°K.

Measurements with tin oxide, SnO_2, were done on a constant speed apparatus[7] at three temperatures: 77, 293 and 640° K. A "thin" absorber was used at each temperature. The absorber thickness was chosen so that the effects were almost the same at all temperatures.

In all cases the absorption spectrum of SnO_2 was an incompletely resolved doublet. To analyze the complex spectrum we used the technique of graphical resolution into components, making use of data on the dependence of the width of a single line on the value of the observed effect.[6]. We found that the absorption spectrum of SnO_2 could be well represented by two lines of natural width separated by an amount Δ.

Figure 2 shows an example of such a resolution. The points correspond to the experimentally observed absorption spectrum of tin oxide (thickness 4.42 mg/cm²) found using the resonance counter. These points fall nicely on the curve found by the graphical analysis, which is the sum of two Lorentzian shapes shifted from one another by Δ = 0.5 mm/sec; their widths are the width of the absorption spectrum for Mg_2Sn for the same size effect.

A similar procedure was used for spectra measured at the other temperatures. The results of the resolution are given in the table, and show that the splitting is constant in this temperature range and equal to 0.50 ± 0.02 mm/sec. The error given is the statistical accuracy of the measurements of the SnO_2 absorption spectrum. If one assumes that the width of the lines constituting the doublet differs in tin oxide from the width of the absorption line for Mg_2Sn, the observed spectrum for SnO_2 can be explained with a splitting Δ = 0.50 ± 0.04 mm/sec. Since we know that there is quadrupole splitting in tin oxide,[4] and since our measurements show that the whole broadening of the line can be explained by the doublet character of the spectrum, the value of Δ found here should be ascribed entirely to quadrupole interaction.

The noticeable difference of the present results on the shape of the SnO_2 spectrum from the results of earlier work[1,2,4] can be explained by the fact that the other experiments used a source of SnO_2. Because of the large width of the line, which is an unresolved triplet, the true nature of the tin oxide spectrum could be deduced only indirectly (from the dependence of the line width and size of the effect on absorber thickness and temperature), which caused an incorrect interpretation.

In[4], where the quadrupole character of the SnO_2 spectrum was established by direct observations, the single crystal samples were too thick (15—20 mg/cm²) for accurate measurements of line shape.

The large value of Δ found in the present work by direct measurements is confirmed by the data of[8], where the perturbed $\gamma-\gamma$ correlation of the Sn^{119} γ rays in SnO_2 was studied. They found Δ = 0.45 ± 0.10 mm/sec.

In metallic white tin our main interest was the quadrupole interaction, which according to the data,[1,3] depends strongly on the temperature of the crystal.

The investigations in[1-4] were done with a SnO_2 source, and it was assumed that the spectrum is a single Lorentzian line. Since the splitting found by us in SnO_2 has the same order of magnitude as the value of Δ for β-Sn reported in[1,3], these data need to be improved.

Our measurements on metallic tin were done at 77 and 293° K under the same conditions as described above for SnO_2. The main difficulty was the preparation of the absorber for measurements at 77° K, since it had to be sufficiently thin with respect to resonance absorption. To avoid possible sources of error, both absorbers were made by the same technique of rolling. The thinnest plates, 6 mg/cm² thick, were used for the measurements at liquid nitrogen temperatures. At room temperature the measurements were made with an ab-

Absorber thickness, mg/cm²	T, °K	Δ, mm/sec	Absorber thickness, mg/cm²	T, °K	Δ, mm/sec
10.00	640	0.50	2.30	77	0.52
9.00	290	0.50	2.30	77	0.48
4.42	289	0.50			

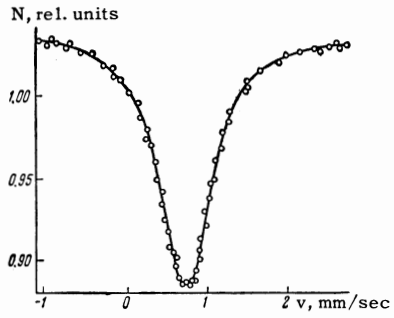

FIG. 3. Absorption spectrum for 22.4 mg/cm² β-Sn absorber at 290°K.

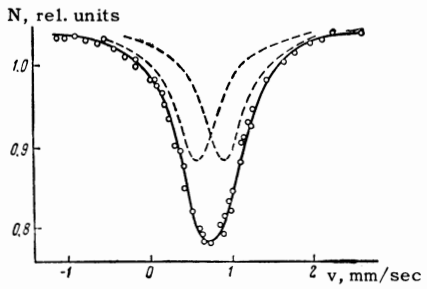

FIG. 4. Absorption spectrum for 6 mg/cm² β-Sn absorber at 77°K.

sorber 22.4 mg/cm^2 thick. The spectra obtained are shown in Figs. 3 and 4.

Both spectra consist of a single line. If we assume that the spectrum is an unresolved doublet produced by lines having the natural width, the graphical analysis gives a splitting $\Delta = 0.32 \pm 0.02$ mm/sec at 77° K and $\Delta = 0.25 \pm 0.02$ mm/sec at 293° K. If one assumes that the doublet components themselves may be broadened, the result becomes less definite; one can only say that the total line width decreases on heating.

Thus, on the basis of our measurements, one may conclude that:

1) the broadening of the line in tin oxide is caused entirely by quadrupole interaction, whose magnitude $\Delta = 0.50$ mm/sec is independent of temperature in the temperature interval 77—638° K which was studied;

2) in metallic white tin the quadrupole splitting is smaller than that reported earlier,[1,3] and drops when the absorber is heated.

It should be specially noted that results obtained using a source of SnO_2 and assuming that its spectrum is a dispersion curve must be corrected for the splitting of the line.

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