MAGNITUDE OF THE QUADRUPOLE INTERACTION OF THE Sn^{119m} NUCLEUS WITH THE CRYSTAL LATTICE

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The quadrupole interaction of the Sn^{119m} nucleus with the lattice of β-Sn and other tin compounds was measured. It is shown that the discrepancy in previously published data is connected with a possible instrumental splitting of the measured line. A cause of such instrumental splitting is indicated.

THE quadrupole interaction of the Sn^{119m} nucleus (excitation energy 23.8 keV) with the lattice of β-Sn and other tin compounds has been studied by the method of recoilless resonance absorption in many experiments. There is an apparent contradiction between the experimental results of Shpinel's group [1-4] and those of authors in other countries. [5-7]

The experimental width of the resonance absorption line $2\Gamma_{exp} = 1.2-1.8$ mm/sec found in [5-7] is much larger than the theoretical value $2\Gamma_{th} = 0.63$ mm/sec (5×10^{-8} eV), calculated from the measured lifetime of the excited state. [8] No splitting of the line was observed. If the observed experimental broadening of the line is attributed entirely to the quadrupole splitting of the spin $\frac{3}{2}$ level at 23.8 keV in Sn^{119m} in the field of the tetragonal β-Sn lattice, one can estimate an upper limit for the splitting $\Delta = \frac{1}{2} eQ\partial^2V/\partial z^2$, which gives $\Delta = 3 \times 10^{-8}$ eV. [5]

On the other hand, Shpinel' et al [1-4], with an experimental width of the level equal to $2\Gamma_{exp} = 0.9$ mm/sec, observed a splitting of the line and, from this splitting, directly measured the value of Δ, which was $(11.0 \pm 1.5) \times 10^{-8}$ eV (1.46 mm/sec) The authors explained the discrepancy between their results and those mentioned above [5-7] in terms of the temperature dependence of the splitting which they found. It was shown that the splitting $\Delta = 11.0 \times 10^{-8}$ eV was observed with the source and absorber at liquid nitrogen temperature, and with their thicknesses less than 5 and 8 mg/cm^2 respectively, i.e., under conditions which were not met in [5-7].

In our measurements both source and absorber were at T = 83°K, and their temperatures were regulated. The source was a 7.15 mg/cm^2 foil of β-Sn (0.1% Sn^{112}, 2.3% Sn^{119}, 94% Sn^{118}), irradiated with a total neutron flux of 2.1×10^{20} neuts/cm^2. For absorbers, we used foils of β-Sn of various thicknesses and also other compounds of tin. A simplified block diagram of the arrangement is shown in Fig. 1.

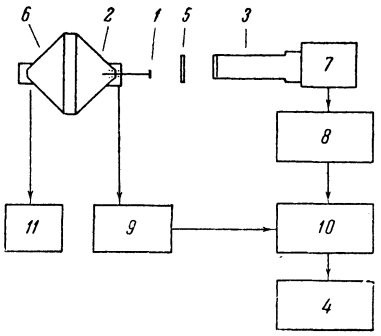

FIG. 1. Simplified block diagram of equipment: 1 – source, 2 – measuring speaker, 3 – photomultiplier, 4 – 100-channel pulse-height analyzer, 5 – absorber, 6 – driving cone, 7 – amplifier, 8 – single-channel pulse discriminator, 9 – modulator, 10 – "rejection" circuit, 11 – audio-frequency generator.

The source 1, fixed to the voice coil of an electrodynamic loudspeaker 2, carried out sinusoidal oscillations with a frequency of 400 cps. Pulses from the photomultiplier 3, after amplification, amplitude selection and standardization, were modulated by the sinusoidal voltage from the speaker coil 2, after which they were analyzed in the AI-100 one-hundred channel analyzer 4. The resonance absorption curves shown below required an exposure time of 40 min. Since the period of vibration of the source is incomparably greater than the lifetime of the nuclei in the excited state, the operating frequency of 400 cps could not produce any significant broadening of the absorption due to acoustic modulation of the frequency of the γ quanta. [9]

Figure 2a shows a typical resonance absorption curve with a source and absorber of white tin. No

Compound and type of lattice*	Thickness, mg/cm²	$2\Gamma_{exp}$, 10^{-8} eV	Δ, 10^{-8} eV	Isomer shift, 10^{-8} eV
Sn (β), T	46	12.6±2	$1.5 \leqslant \Delta \leqslant 4$	—
Sn (β), T	13.9	12.4±2		—
SnO_2	10.8	10±1.5	<3	19 ±3
SnO, T	19.7	18.2±3	~8	0.7±0.5
Cd Sn As_2,T(Ch)	17.8	11.4±2	⩽3	7.6±1.5

*Lattice type: T – tetragonal, T(Ch) – tetragonal chalcopyrite type.

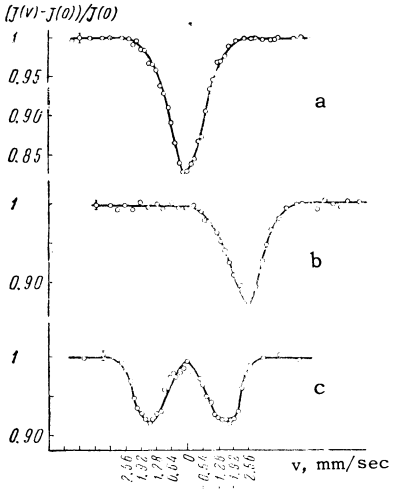

FIG. 2. Experimental resonance absorption curves (twice the statistical error is indicated): a – Source and absorber of β-Sn at liquid nitrogen temperature; b – SnO_2 absorber (positive velocity corresponds to source and absorber approaching one another); c – instrumental splitting of the line.

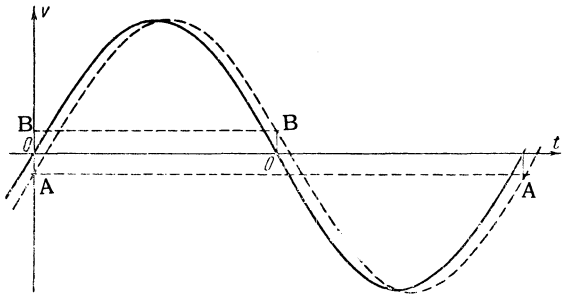

FIG. 3. Solid curve v(t) is the true velocity of the source; the dashed curve shows the voltage giving amplitude modulation of the pulses (shifted relative to the first curve by 10°).

splitting of the line was seen, and from the broadening one can set limits on the splitting of $1.5 \leq \Delta \leq 4 \times 10^{-8}$ eV.

Figure 2b shows the resonance absorption curve using a filter of SnO_2 (10.8 mg/cm²). The chemical shift is $\delta = 19 \times 10^{-8}$ eV, in good agreement with other work. But again there is no apparent splitting of the line.

An examination of the table, in which we give the results of measurements with different absorbers at liquid nitrogen temperature shows that our data for estimating the quadrupole splitting in the β-Sn lattice are in satisfactory agreement with the results of [5-7] and are in contradiction with the experimental results of Shpinel' et al.[1-4] A possible reason for the discrepancy is that in [1-4] the "instrumental" splitting was not taken into account. In equipments with varying velocity of motion in two directions and using amplitude modulation of the pulses, as in our equipment or that used in [1-4], an instrumental splitting of the resonance absorption line may occur because of a time displacement (phase shift) between the actual motion of the source and the related voltage which gives the amplitude modulation of the pulses. An example of such an instrumental splitting is shown in Fig. 2c, where the unsplit line shown in Fig. 2a is split in two because of the phase shift of 5° which is present. The inevitability of such splittings is explained by Fig. 3, from which one sees that the phase shift cited results in the recording of the true velocity null O at two points A and B which are symmetrically displaced relative to the assumed zero velocity.

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