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ISOMER SHIFTS FOR THE 23.8-*kev GAMMA TRANSITION IN* Sn^{119}

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By measuring the resonance absorption of the γ quanta by nuclei in crystals, we have determined the isomer shifts for the 23.8-kev transition of Sn^{119} in several compounds of tin. We discuss a possible qualitative interpretation of the shifts; according to this interpretation, when the Sn^{119} nucleus is excited there is an increase in the effective radius of the proton distribution in the nucleus and the proton core of Sn^{119} in the excited state does not have spherical symmetry.

THE method of resonance absorption of γ quanta can be used to measure small changes in the energy of nuclear γ transitions and, in particular, the magnitudes of the isomer shifts [1] which result from the interaction with the atomic electrons of the nuclear charge in the ground and excited states. We have previously noted [2] the presence of such shifts for the 23.8-kev γ transition in Sn^{119}. Recently a detailed investigation of such shifts for the 14.4-kev γ transition in Fe^{57} has been made by de Benedetti, Lang, and Ingalls [3] and by Walker, Wertheim, and Jaccarino.[4]

In the present work we have measured the isomer shift for the 23.8-kev γ transition of Sn^{119} in various tin compounds. The measuring technique and apparatus are the same as those we used earlier.[5,6] The measurements were made with a source of Sn^{119m} in the form of SnO_2; in this source there is no quadrupole splitting of the emission line and the effect of recoilless emission of γ quanta is large at room temperature. The source was kept at room temperature in all measurements, while the absorbers of various crystalline compounds of tin were at liquid nitrogen temperature or at room temperature. Some of the results have been published previously;[2,5] for some of the substances previously measured, improved data are given in the present paper.

Typical resonance absorption spectra are shown in Figs. 1 and 2. In Fig. 1 we give the resonance absorption spectrum for SnF_2, in which the absorption line is split into two components as a result of quadrupole interaction of the excited Sn^{119} nucleus with the electric field gradient in the crystal. The value of the isomer shift δ was determined relative to the energy of the γ transition in a SnO_2 crystal at room temperature (i.e., the emission line of the source). Figure 2 shows the absorption spectrum for a $SnCl_2$ crystal, in which there is no quadrupole splitting. Similar resonance absorption spectra were taken for eleven tin compounds with the absorbers at liquid nitrogen temperature. The results of the measurements are shown in the table. For some of the compounds the isomer shift was also measured with the absorber at room temperature. Within the limits of error, the isomer shift was the same as at liquid nitrogen temperature*; the exception was $SnNb_3$,

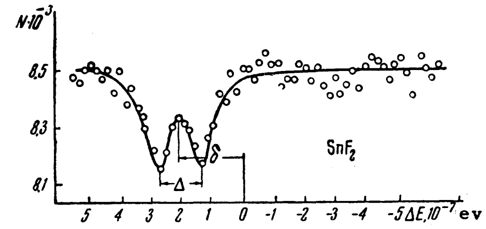

FIG. 1. Resonance absorption spectrum for SnF_2 polycrystal at liquid nitrogen temperature ($\Delta E = E_0 v/c$, where E_0 = 23.8 kev, v is the velocity of the absorber and c the velocity of light; N is the total number of pulses counted).

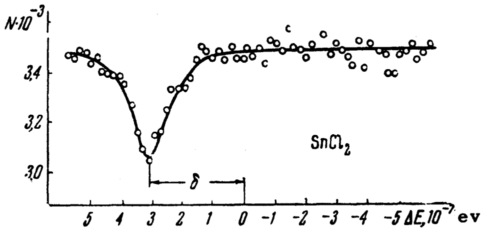

FIG. 2. Resonance absorption spectrum for $SnCl_2$ polycrystal at liquid nitrogen temperature (notation the same as in Fig. 1).

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*The existence of a temperature dependence of the isomer shift for the β-Sn crystal [7] which we reported earlier has not been confirmed by the later measurements.

Isomer shifts* of the 23.8-kev γ transition of Sn^{119}

Chemical compound	Isomer shift, 10^{-8} ev	Chemical compound	Isomer shift, 10^{-8} ev
SnO_2	$\leqslant 1$	SnO	22,0±1.5
$SnCl_4 \cdot 5H_2O$	2,2±1.0	$SnCl_2$	30.6±3.0
SnI_4	13.0±2.0	$SnBr_2$	1.6±0.7
SnS_2	8,5±2,0	β-Sn	22.0±2.0
$(NH_4)_2 \cdot SnCl_6$	3,3±1.5	$SnNb_3$	18.0+1.5
SnF_2	23.5±3,0		

*Shifts measured at liquid-nitrogen temperature relative to γ-transition energy in SnO_2 crystal at room temperature.

for which the relative change in energy was of the order of 1.5×10^{-12} for a change in temperature from liquid nitrogen to room temperature.

In addition to the previously observed cases of the β-Sn and SnO crystals,[5,8] quadrupole splitting of the absorption line was found only in SnF_2 (Fig. 1). For this crystal the magnitude of the splitting Δ was $(15.5 \pm 2.5) \times 10^{-8}$ ev and (as for the SnO crystal) was not strongly temperature dependent (unlike the case of β-Sn[7]).

From the data in the table we see that the isomer shifts for the 23.8-kev γ transition of Sn^{119} do not show such clear regularities as one finds for the 14.4-kev transition in Fe^{57}. It appears that the magnitude of the shift is affected not only by the valence of the tin atom in the particular compound but also by the chemical activity (electronegativity) of the other atoms, and by the crystal lattice structure. The latter is confirmed, for example, by the existence of an isomer shift between the two tin modifications β-Sn and α-Sn,[9] which are identical chemically but have different crystal structures.

We may note, however, that as a rule divalent tin compounds have a larger isomer shift than do tetravalent compounds. In the outer shell of the tin atom there are two p electrons, which give a much smaller contribution to the isomer shift than do the s electrons. We can assume that for divalent compounds of tin it is just these two p electrons that participate in the chemical bond; the valence electrons of the next shell (the two s electrons) only enter into the chemical binding for the tetravalent compounds, and this results in a marked change in the isomer shift. According to this interpretation one would conclude that the density of the s-electron wave function in the region of the nucleus is less in tetravalent compounds than in divalent compounds. The isomer shift is proportional to the product of the change in the square of the effective charge radius of the nucleus and the change in the square of the electron wave function at the nucleus for the two different compounds. Comparing the isomer shifts for di- and tetravalent compounds of tin, we can write

$$E_{\mathrm{II}} - E_{\mathrm{IV}} \sim (R_{\mathrm{e}}^2 - R_0^2)\,[\,|\psi(0)|_{\mathrm{II}}^2 - |\psi(0)|_{\mathrm{IV}}^2],$$

where R_e and R_0 are the effective charge radii for the Sn^{119} nucleus in the excited and ground states, $\psi(0)$ is the electron wave function (mainly from s electrons) at the nucleus. The left side of this equality is positive; the term in square brackets on the right is also positive (according to the interpretation given above). Consequently $R_e^2 > R_0^2$, i.e., when the Sn^{119} is excited the effective radius of the charge distribution increases. The excitation of the Sn^{119} nucleus may be regarded as the excitation of the odd neutron (or of a group of neutrons). Nevertheless, the proton-magic core of the Sn^{119} nucleus does not remain inert in such an excitation, as is convincingly shown by the change in the radius of the charge distribution in the nucleus when it changes to the excited state. The presence of quadrupole interaction shows that the proton-magic core of the Sn^{119} nucleus does not have a spherically symmetric shape (at least in the excited state). These facts can be understood if we assume that the outer neutrons exert a polarizing force on the proton core of the nucleus, causing it to deform and changing the effective radius when there is an excitation.

A more detailed (quantitative) interpretation of the observed isomer shifts cannot be given, since the electronic wave functions are not known for the tin atom; the interpretation is complicated by the possible influence on the isomer shift of the crystal structures of the tin compounds.

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