where B_I is the Brillouin function. In other words, we have the result that the effective nuclear gyromagnetic ratio is equal to the electronic gyromagnetic ratio.

In the case of nonmetals, however, we have a developed hyperfine structure of the paramagnetic resonance, and it is difficult to saturate all its components. Simple calculation shows that upon total saturation of the hyperfine structure components corresponding to a nuclear spin component equal to m, we get for the nuclear polarization

$$f = \frac{[I(I+1)-m^2](e^{2\delta}-e^{-2\delta})-m(e^{\delta}-e^{-\delta})^2}{2I[2(I+1)+(I-m)e^{2\delta}+(I+m)e^{-2\delta}]}. \quad (2)$$

In particular, we have for $\delta \ll 1$

$$f = \frac{I(I+1)-m^2}{I(2I+1)}\delta, \quad (3)$$

and for $\delta \gg 1$

$$f = (I+1+m)/2I, \quad \text{if } m \neq I,$$
$$f = 1/2(I+1), \quad \text{if } m = I. \quad (4)$$

We see thus that for small δ it is more advantageous to saturate the lines with m = 0 or m = $\pm\frac{1}{2}$ (depending on whether I is integral or half-integral) to obtain the largest f. In the case of large δ it is advantageous to saturate the line with m = I − 1. In particular, in the latter case we get $f \approx 1$ for $\delta \gg 1$, as can easily be understood (practically only the level M = $-\frac{1}{2}$, m = I will be occupied).

Experimentally the magnitude of the nuclear polarization can be measured from the intensity of the unsaturated paramagnetic resonance lines, from the intensity of the nuclear magnetic resonance lines (transitions $\Delta M = 0$, $\Delta m = \pm 1$), or, in the case of the polarization of radioactive nuclei, from the angular anisotropy of the γ-radiation.

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MEAN FREE PATH OF ELECTRONS IN HIGH-PURITY TIN

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THE production of many pure metals has been made possible by to the development of the method of multiple zone crystallization ingots.[1] Thus, multiple zone crystallization of tin ingots[2] combined with prolonged high-temperature heating of this metal in high vacuum[3] has yielded tin of very high purity.

The purification of the tin was controlled by measuring the residual resistance $\delta = R_{4.2}/R_{room}$ of samples taken from different sections of the thoroughly heated and re-crystallized ingot. (Here $R_{4.2}$ is the resistance of the sample at 4.2°K and R_{room} — its resistance at room temperature.) While working with high-purity tin, $R_{4.2}$ was found to depend on the cylindrical-sample, wire diameter, owing to the fact that this diameter became commensurate with the electron mean free path.

Figure 1 A presents δ as a function of the cylindrical-wire diameter for tin with $\delta_\infty = 1.8 \times 10^{-5}$.

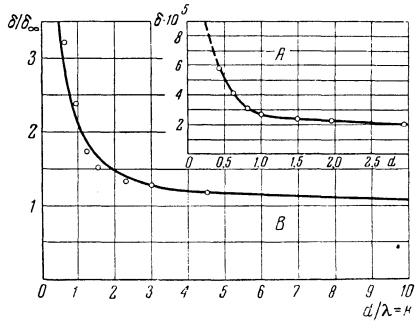

FIG. 1. A — Variation of residual resistance of tin with $\delta_\infty = 1.8 \cdot 10^{-5}$ with the diameter of the cylindrical wires. B — theoretical curve[4] of δ/δ_∞ as a function of $k = d/\lambda$ for p = 0; d — diameter of the cylindrical wires, λ — electron mean free path, o — experimental data for $\lambda = 0.65$ mm.

It is known that the investigation of the electric resistances of thin films and metal wires is the oldest method of determining the electron mean free path in these materials. This problem was theoretically investigated for cylindrical wires by Dingle.[4] His work contains a table of σ_∞/σ for arbitrary k, along with the formulas

$$\frac{\sigma_\infty}{\sigma} = 1 + \frac{3}{4}\frac{1-p}{k} \quad (k \gg 1),$$

$$\frac{\sigma_\infty}{\sigma} = \frac{1-p}{1+p}\frac{1}{k} \quad (k \ll 1) \qquad (1)$$

(where $k = d/\lambda$, d is the wire diameter σ_∞ the conductivity of the bulk metal, and p the probability that the electron scatters elastically). The curve of Fig. 1B displays this function graphically for $p = 0$. The dots represent the experimental values. They fit the theoretical curve best when $\lambda = 0.65$ mm.

It is known that

$$\sigma_\infty/\lambda = 1/\rho_\infty\lambda = (8\pi/3)^{1/3} e^2 (n_A n)^{2/3}/h = 7.1 \cdot 10^7 (n_A n)^{2/3}, \qquad (2)$$

where n_A is the number of electrons per unit volume, and n their number for one atom of metal. For tin at room temperature, $\rho = 1.1 \times 10^{-5}$ ohm-cm, while $\rho_\infty^{4.2} = 1.98 \times 10^{-10}$ ohm-cm. Using this value we find, according to formula (2), that at 4.2°K

$$\lambda n^{2/3} = 5.7 \cdot 10^{-2}$$

or $n \approx 0.8$. This value agrees with Borovik's[5] data, obtained for tin by experimental investigations of galvano-magnetic phenomena at low temperatures. The results of the present work, as well as data of other authors who investigated the influence of size on the electric resistivity of tin are given in a table below.

	Purity of specimens	T° K	λ, cm	$\rho\lambda \cdot 10^{11}$ ($\Omega \cdot cm^2$)	n	State of specimen
Present work	$\frac{R_{4.2}}{R_{294}} = 1.8 \cdot 10^{-5}$	4.2	$6.5 \cdot 10^{-2}$	1.3	0.8	Crystal
Andrew[6]	$\frac{R_{3.8}}{R_{291}} = 1.8 \cdot 10^{-4}$	3.8	$9.5 \cdot 10^{-3}$	2.0	0.43	Polycrystalline film
Kunzler and Renton[7]	$\frac{R_{4.2}}{R_{273}} = 3.5 \cdot 10^{-5}$	4.2	$4.5 \cdot 10^{-2}$	2.3	0.35	Crystal

All these data are in full agreement with the results obtained when investigating the anomalous skin effect in tin. Really, Chambers[8] has obtained by similar investigations of tin $\rho\lambda = 1.0 \times 10^{-11}\ \Omega\ cm^2$ and $n \approx 1.1$.

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