OBSERVATION OF "FINE STRUCTURE" OF THE MAGNETIC ANOMALITY OF THE ISOMER SHIFT

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It has been observed that the temperature dependence of the shift of the Mossbauer resonance line for the impurity atoms ^{119}Sn in alloys based on nickel have near the Curie temperature a complicated structure that consists of narrow maxima and minima.

Preston, Hanna, and Heberle [1], in an investigation of the temperature dependence of the shift of the resonance line in the Mossbauer spectrum of metallic iron, have observed that the isomer shift of the line experiences a jumplike change at the Curie temperature. Preston [2] has investigated this phenomenon in detail and has shown that an abrupt change in the shift occurs in a narrow range of temperatures, not exceeding 0.3°. These data were interpreted in [3] as the result of a change in the electronic wave functions under the influence of exchange interaction. This interpretation, however, does not explain the abrupt jump of the electron density at the Curie point, which seems to contradict the notion that the magnetic transition is a second-order phase transition [2]. Unfortunately, metallic iron has remained to this day the only example in which this nontrivial phenomenon has been investigated in detail.

We have undertaken a study of the temperature dependence of the isomer shift in the vicinity of the Curie temperature (T_C), using the Mossbauer effect on the impurity atoms ^{119}Sn in metallic ferromagnetis. It was recently observed that this dependence has a complicated structure consisting of maxima and minima whose widths vary from several tenths of a degree to 0.1° (or less). This result was obtained by us for a number of alloys based in Ni (including impurity Sn atoms in pure Ni). The behavior of the isomer shift for ^{119}Sn in pure Ni and in alloys is qualitatively similar. We present below the main results for ^{119}Sn (0.5 at.%) in an alloy Ni + 6 at.% Cr, which was investigated by us in greatest detail.

The samples were obtained by melting the components (their purity was not worse than 99.95%) in vacuum, followed by homogenization at 1000°C for 24 hours. The Curie temperature of the alloy ($T_C \approx 335$°K) was determined from the temperature dependence of the hyperfine magnetic fields. The measurements were made in the temperature range 309 – 350°K with a constant-acceleration spectrometer with an NTA-512 multichannel analyzer with 0.031 mm/sec per channel. In two halves of the analyzer memory we measured simultaneously two spectra, and the results of these two measurements were averaged. The temperature stability was 0.05°, and the temperature gradient over the sample did not exceed 0.1°. The shift was determined by calculating the "center of gravity" of the line. The statistical error was negligible and the measurement error was determined, in the main, by the stability of the spectrometer. The stability was monitored by regular measurements of the shift for a "standard" absorber (0.5 at.% Sn in a Pd matrix) at room temperature. The changes of the line position for the "standard" absorber, after prolonged time intervals (several months), did not exceed 0.1 channel as a rule. Recognizing that the shift was determined relative to the "standard" by averaging the data for two spectra, we assume that the rms deviation for each point does not exceed 0.1 channel, corresponding to 3×10^{-3} mm/sec. In some temperature intervals we repeated the measurements with an interval up to 6 months between measurements; the results of such measurements were in good agreement with one another.

Figure 1 shows part of the obtained data (for the temperature range 332 – 350°K). We see that in the temperature region below 339°K the line shift experiences abrupt variations in the form of narrow minima and maxima. The shift had a similar temperature dependence also at lower temperature, except that with increasing distance from T_C the maxima and minima become more rare. By way of example, Fig. 2 shows the results of the measurements for the interval 390 – 318°K. Some of the peaks (e.g., the maximum at 333.75°K) have a width on the order of 0.1°. It is possible that the actual widths of some of the peaks are even smaller, but the measurement accuracy was limited by the temperature stability attainable in this experiment. For the same reason one cannot exclude the possibility that sight was lost of certain singularities of width much less than 0.1°. No abrupt changes in the area of the resonance line or in its width were observed.

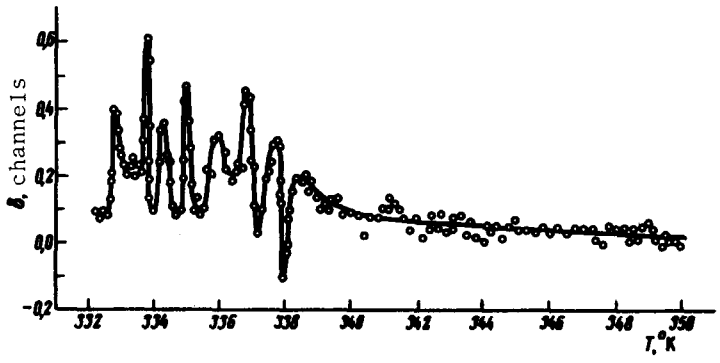

Fig. 1

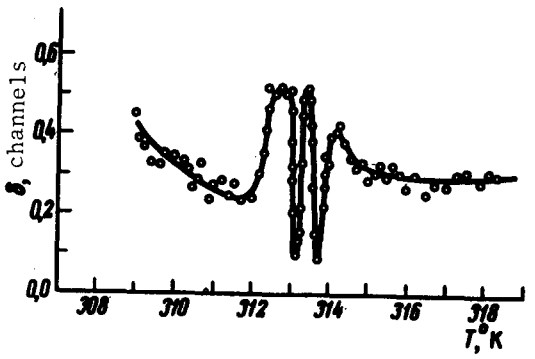

Fig. 2

Fig. 1. Temperature dependence of the shift δ of the resonance line in the temperature range 332 — 350°K. The shift was determined relative to a "standard" absorber (0.5 at.% Sn in Pd at room temperature). One channel corresponds to 0.031 mm/sec.

Fig. 2. The same as in Fig. 1, for the temperature range 309 — 318°K.

Since the data obtained by us on the "fine structure" of the temperature dependence of the isomer shift are so far the only available ones, and this structure has turned out to be rather complicated, we are unable at present to offer a well-founded interpretation of the observed phenomenon. It is reasonable to assume, however, that the variation of the electron density in the region of the nucleus are connected with changes in the electronic wave functions near T_c, induced by the effective exchange field. This can give rise in the electron-state density to singularities (possibly similar to the known singularities that occur in metals placed in an external magnetic field). The change in temperature brings about a change in the exchange field, and consequently a shift of the singularities as functions of the electronic-state densities relative to the Fermi level. Naturally, the abrupt changes in the densities of the electronic states on the Fermi surface can be reflected in abrupt changes of the isomer shift. If such an interpretation turns out to correspond to reality to a certain degree, then measurements of the isomer shift can serve as a new method for the spectroscopy of the electronic states in magnetic metallic systems. To explain the physical nature of the observed phenomenon we propose to carry out detailed investigations for different alloys with a better temperature resolution.

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[3] S. A. Alexander and D. Treves, Phys. Lett. 20, 134 (1966); R. Ingalls, Phys. Rev. 155, 157 (1967).

MAGNETIC MOMENT OF Mn ATOMS IN THE $Ni_{1-x}Mn_x$ SYSTEM

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The high-frequency parts of the NMR spectra of $Ni_{1-x}Mn_x$ alloys have been resolved for the first time as a result of the different orientations of the magnetic moments of the Mn atoms. This has made it possible to estimate the local moments of Mn.

The atomic moments in the $Ni_{1-x}Mn_x$ system were investigated both experimentally and theoretically [1-4]. Neutron-diffraction investigations [2] have shown that in the disordered state we have $\mu_{Mn} = 3\ \mu_B$ and $\mu_{Ni} = 0.6\ \mu_B$ at concentrations $x < 6$ at.%, and that the moments decrease at $x > 6$ at.%. However, neutron-diffraction methods of determining the local magnetic moments in systems having no ideal order do not make it possible to determine the true values of the