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M. P. Petrov and G. A. Smolenskiĭ. Distribution of Spin Density and Nuclear Echo in Magnetic Crystals.

The magnetic moments of nuclei are natural magnetic probes in solids, and make it possible to investigate the spatial distribution of magnetic fields and of the spin density in objects of interest to us.

In magnetic crystals there is a so-called spin-density transport effect,[1,2] i.e., the appearance of spin decompensation of electron shells of non-magnetic ions. At those points where the nuclei of nonmagnetic ions are located, a magnetic field appears. The intensities of such fields may be low, but nonetheless it can be readily measured by MNR, owing to the high resolution of this method. The paper contains results of experimental investigations of the spin density at nuclei of non-magnetic ions (Rb^+, F^-, etc.) in the paramagnetic region of the antiferromagnets $RbMnF_3$, $RbCoF_3$, $RbFeF_3$, and $TlMnF_3$. The NMR method has made it possible to observe the spin density both at nuclei of fluorine as well as at nuclei of thallium and rubidium, i.e., to demonstrate experimentally that the electrons with unpaired spins are not localized completely in the shell of the magnetic ions (Mn^{2+}, Co^{2+}, Fe^{2+}), but are distributed over the entire crystal. It turned out that the spin densities at the fluorine and rubidium nuclei have different signs, i.e., there are spatial oscillations of the spin density. The investigated delocalization of the spin density is a direct manifestation of the effects of covalence of the chemical bond and of indirect exchange interaction in nonmetallic solids. It was possible to demonstrate theoretically and experimentally how the character of the crystal symmetry and the electronic structure of the shells of the magnetic ions influence the concrete type of spin-density distribution.[3,5]

The measurement of the fields at the fluorine level in $RbNiF_3$ has also made it possible to trace the temperature behavior of the magnetizations of the sublattices in this ferrimagnet.[6] A new phenomenon was observed, the so-called induced ferrimagnetism, wherein a complicated magnetic structure is produced in the ferrimagnet at temperatures greatly exceeding the Curie point (by a factor 1.5–2), if the sample is placed in an external magnetic field. It was observed in $RbNiF_3$ by the NMR method that at $T_0 > T > T_C$ there exist two oppositely-directed magnetic sublattices, if the sample is situated in an external field ($T_0 \approx 2T_C$). This effect can be easily explained within the framework of the molecular-field theory in the following manner: each sublattice is acted upon by a resultant magnetic field consisting of the external field and the internal effective exchange field. Since the interaction between the sublattices is antiferromagnetic, it follows that at $T > T_0$ the effective field is directed opposite to the external field; with decreasing temperature towards T_0, the resultant field on one of the sublattices vanishes, and the magnetization of this sublattice reverses sign. We note that owing to the nonequivalence of the sublattices (this is the necessary condition) the resultant field of the other sublattice does not reverse sign.

A detailed comparison of the experimental data with calculations within the framework of the constant-coupling method has made it also possible to determine the temperature region where an important role is played by short-range magnetic order.[6,7]

Significantly different values of the field are realized at nuclei under conditions of observation of nuclear resonance in ferrimagnets at temperatures above T_C. In magnetically-ordered crystals the field at the nuclei reaches values of hundreds and thousands kOe, and the intensity of the nuclear resonance increases by several orders of magnitude. Under these conditions, an effective method of investigation is the method of nuclear spin echo in internal fields. Observation of nuclear echo makes it possible to investigate nuclear-relaxation processes, which in magnetic crystals are due to the interaction of the nuclear moment with the ordered electron system, with essentially new relaxation processes taking place here, for example the spin-spin nuclear relaxation due to the interaction of nuclei via emission and absorption of virtual spin waves (the Suhl-Nakamara interaction), are spin-lattice relaxation due to the scattering of spin waves by nuclear moments. An important role is played here by many-magnon processes and by spin-wave damping. The paper presents results of investigations of spin-spin and spin-lattice relaxations of ^{57}Fe nuclei in the ferrimagnet $Y_3Fe_5O_{12}$.

The results of the investigations are contained in the attached bibliography.

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V. A. Alekseev and A. A. Vedenov. Electric Conductivity of Dense Cesium Vapor

The question of the appearance of electric conductivity upon compression of metal vapors was considered in the literature many times.[1] The most interesting is the investigation of the electric conductivity of Cs, which has the lowest ionization potential, 3.9 eV, and critical parameters $p_c = 115$ atm, $T_c = 1775°C$, and $\rho_c = 0.445$ g/cm^3,[2] such that at $T \sim T_c$ rarefied cesium is an ideal weakly-ionized plasma with electric conductivity ~ mho/cm.

Measurements of the electric conductivity of Cs in the transcritical state have been carried out recently at the I. V. Kurchatov Institute of Atomic Energy[3] (analogous experiments were carried out also at the Karlsruhe University, West Germany[4]).

Success in the measurement of the electric conductivity of cesium in the transcritical state is due entirely to the choice of materials, since cesium has a rather high critical temperature and an increased reactivity. From among the insulators we have chosen pure beryllium oxide. The best metal is tungsten and for experiments of short durations it is possible to use niobium.

The experiment is based on the idea of the possibility of producing a liquid piston of the investigated metal, capable of transmitting the working-gas pressure to the zone of high-temperature measurements.

A measurement cell was constructed on the basis of this principle. The body of the cell was made of a tube of electronically-melted niobium 6.3 mm in diameter. A lower electrode of the same grade of niobium was welded to the lower part of the tube with an electron beam, and a capillary of beryllium oxide was tightly placed over the lower electrode. In the upper end of the capillary was inserted the upper electrode of niobium, of 2.5 mm diameter in such a way that the difference between the electrodes, where the cesium was located, was 2–3 mm. A thermocouple in a flat sleeve of beryllium oxide was fastened to the side of the cell. The junction of the thermocouple was placed opposite the gap between the electrodes, with accuracy ±0.2 mm.

To determine the temperature in the cell, the readings of the thermocouple at the housing of the cell were compared with the readings of a thermocouple placed in the zone in lieu of the cesium. The ends of the thermocouple were passed through conical inserts, and the second junction was placed in a dewar with melting ice. The cell length was chosen to accommodate the cesium expanding upon heating. The cell was heated with a tubular heater of molybdenum foil 10 cm long, to which 250 A alternating current was fed. A special mechanism has made it possible to regulate the position of the cell relative to the heater under pressure. The current lead was made in the form of a conical gasket on the lower obturator and served as the lower holder of the heater. The body of the heater was made of stainless-steel sheet and was spot welded along the perimeter of obturator. The thermal insulation of the heater was provided by magnesium-oxide powder filling the space between the heater and the housing. The cell with the heater were placed in a chamber for high-temperature measurements, which was filled with purified argon at the required pressure. Argon of "pure" grade was rid of oxygen, water, and carbon dioxide by passing it under pressure through briquettes made of fine chips of annealed red copper and liquid sodium at 400–450°C. After purification, the argon was fed to a thermal compressor, the action of which is based on liquefying the argon at liquid-nitrogen temperature followed by heating to the required pressures. The thermal compressor was a steel flask of 0.5 liter capacity. The pressure in the chamber was measured with standard manometers. The cesium resistance was determined from the potential difference produced between the niobium electrodes by the flow of direct current, and was recorded with an automatic potentiometer.

The results of the electric-conductivity measurements[3,4] are shown in Fig. 1.

The experimentally observed exponential dependence of the electric conductivity on the density may be due to the interaction of the "free" electrons with the neutral atoms.[5] Indeed, in the cesium density region $0 < n \lesssim n_c$ (where this exponential dependence is observed), the interaction between the electrons bound in different atoms is still not very large; at the same time, the average energy of the "free" electrons, owing to their large polarization interaction with the neutral atoms, decreases by an amount $U_1 = n\hbar^2\sqrt{\pi q}/m$, where q is the total cross section for elastic scattering of the slow electrons by the gas atom. The ion energy in the gas also drops, because of the polarization of the neighboring neutral atoms, by an amount $U_2 = 4n\pi e^2\alpha/r_0$.[6] A decrease of the ionization potential I by an amount $U_1 + U_2$ leads to an exponential growth of the electron concentration with increasing gas density

$$n_e \sim \exp(-I + U_1 + U_2)/2T$$

and (at constant mobility) to an exponential growth of the electric conductivity

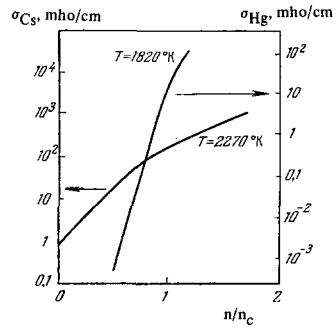

FIG. 1