DYNAMIC POLARIZATION OF DEUTERONS IN A LANTHANUM MAGNESIUM NITRATE CRYSTAL

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We made an attempt to employ the dynamic method of polarization of deuterium nuclei (see[1-7]). The sample used was single-crystal double lanthanum-magnesium nitrate $La_2Mg_3(NO_3)_{12} \cdot 24(H_2O + D_2O)$ to which we added 1% of Nd^{142} with part of the ordinary water of crystallization replaced with heavy water. A crystal approximately 1 cm^3 in volume was grown from a solution of partially dehydrated nitrate salts of lanthanum, magnesium, and neodymium in heavy water. The solution was more than 90% deuterated. Mass spectroscopic analysis has shown, however, that the deuterium content in the crystal was 42%.

The dynamic polarization was effected by the solid-effect method[8] using apparatus described in [9,10]. The experiments were carried out at 37 Gc/sec (magnetic field 10 kOe) and at 1.4°K. The unamplified nuclear magnetic resonance (NMR) signal of the deuterium was lower than the noise level of the autodyne spectrometer employed. An intense NMR signal was observed after the microwave power was switched on (see Fig. 1).

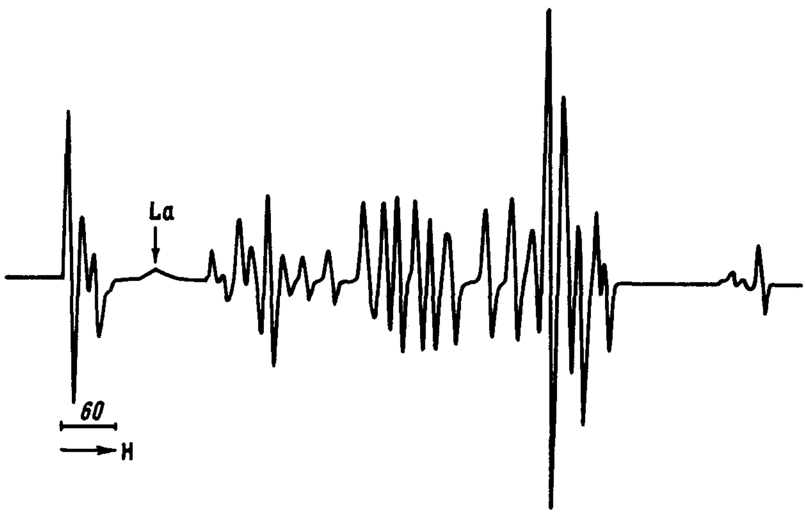

Figure 1. Typical spectrum of NMR signal of deuterium in a crystal of $(0.99La, 0.01Nd)_2Mg_3(NO)_{12} \cdot 12H_2O \cdot 12D_2O$ at 6.5 Mc/sec and 1.4°K.

The NMR spectrum of deuterium consists of several partially unresolved lines symmetrical about the center. Such a spectral structure is due to the quadrupole splitting of the Zeeman levels and to the nonequivalent positions of the deuterium atoms in the crystal lattice.

The different intensities of the spectral components that were symmetrical about the center could be attributed to the appreciable polarization of the individual groups of the deuterium atoms, and could be used to determine the attained polarization, as was done in [11]. Indeed, the spin temperature T_s of the deuteron system can be determined from the ratio of the intensities of the symmetrical components of the spectrum

$$\varkappa = \frac{n_0 - n_{-1}}{n_1 - n_0} = \exp(-\ 2\mu_d H/kT_3)$$

where n_{-1}, n_0, and n_1 are the populations of the Zeeman levels with deuteron spin projections -1, 0, and 1, respectively; μ_d is the deuteron magnetic moment, and positive polarization is assumed. This expression is valid when the Zeeman level populations have Boltzmann distributions. However, the observed difference in the intensities of the symmetrical lines had an irregular character both within a single experiment and in several series of experiments. In some cases $\varkappa$ reached values 0.15- 0.20, which would correspond to a polarization p = 77 - 84%, much higher than the theoretical value 68%. At the same time, the sums of the intensities of any two symmetrical lines, proportional to the polarization of a given group of deuterons $[p \sim n_1 - n_{-1} = (n_1 - n_0) + (n_0 - n_1)]$ retained almost a constant value during different instants of the experiment, although $\varkappa$ fluctuated strongly in the 0.15 - 1.1 range. These facts indicate that the spin temperature concept cannot be applied to a nuclear system immediately after dynamic polarization, probably because of the non-equidistant spacing of the deuteron Zeeman levels, owing to the presence of quadrupole splitting. The onset of equilibrium inside the nuclear system as a result of the spin-spin interaction should become manifest, at first glance, in the relaxation of the amplified NMR signals of the deuterium to a thermal equilibrium, from which one can determine the time necessary for a single spin temperature to set in.

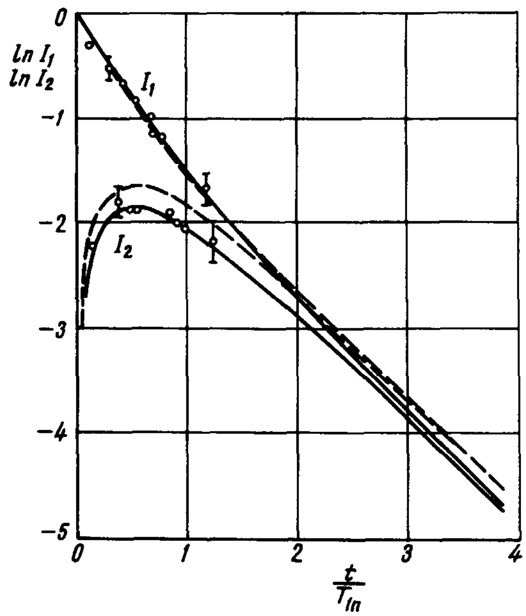

Figure 2

Relaxation curves of NMR signals of deuterium at 1.4°K. I_1 and I_2 denote the amplitudes of the lines constituting a symmetrical pair, normalized to unity. The solid curves are calculated under the assumption that $T_s >> T_{1n}$, dashed curves - $T_s \ll T_{1n}$.

Figure 2 shows the calculated relaxation curves for a pair of symmetrical signals under two extreme assumptions: the time for the spin temperature to set in is 1) appreciably shorter than the deuteron spin-lattice relaxation time T_{1n}, and 2) much larger than T_{1n}. Within the limits of their errors, the experimental points can be equally well described for either of these cases with $T_{1n} \simeq 50$ min. It must be pointed out that the spin temperature can apparently be established by rotating the crystal following the dynamic polarization about an axis perpendicular to the magnetic field.

Thus, measurement of the polarization cannot be carried out by comparing the intensities of two symmetrical NMR signals of deuterium. The lower limit of the attained polarization (about 4.5%) can be determined from the fact that the amplified signal exceeded the noise level by a factor more than 300. Apparently a polarization larger than 10% can be obtained in a 20 kOe magnetic field and at 1°K, which is much higher than the value of polarization (about 1.2%) obtained in solid deuterium [12].

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RENORMALIZATION OF CONSERVED CURRENTS BY SYMMETRY BREAKING

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A study of the influence of octet asymmetry on the strange current of the SU(3) 8-multiplet has demonstrated the renormalizability of the corresponding vector constant[1].

The strange current and the octet breakdown are vectors from the point of view of the V-isogroup.[1)] We therefore consider the change in the V-spin current when V-symmetry is broken.

The correction to the current of the i-th component of the V-spin, necessitated by the isovector disturbance along the third axis, can be written in the form

$$a_1\delta_{i3} + a_2[V_iV_3] + a_3\{V_iV_3\} \tag{1}$$