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DETERMINATION OF THE CONSTANTS OF HYPERFINE INTERACTION BETWEEN THE DEUTERIUM NUCLEI AND THE INTRAMOLECULAR FIELDS IN THE $N^{14}D_3$ MOLECULE

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The ammonia molecule NH_3 has been investigated by microwave spectroscopy methods more thoroughly and fully than any other polyatomic molecule [1]. The theoretical calculation and observation of the hyperfine structure (hfs) of its inversion spectrum are the subject of [1 - 5]. This molecule is of particular interest in connection with the use of molecular generators as frequency standards [6].

Following the detailed investigation of the "light" ammonia molecule, interest arose in the determination of the character of the hyperfine interactions (determination of the quandrupole and magnetic coupling constants) of deuterium nuclei with the intramolecular fields in the isotopically substituted ND_3 molecule.

The procedure developed in [3] for calculating the hfs of the inversion transitions of the $N^{14}H_3$ molecule was extended to include the case of $N^{14}D_3$ [7] and turned to be exceedingly laborious. By using the data for $N^{14}H_3$ [3 - 5] it was possible to estimate the majority of the hyperfine interaction constants for the $N^{14}D_3$ molecule [7]. This manner, obviously, can not be used to estimate the electric quadrupole interaction of the deuterium nuclei with the intramolecular field eq_jQ_D, since the proton has no quadrupole moment.

An experimental measurement of the hfs of the inversion lines of $N^{14}D_3$ [8] using a spectroscope with Stark modulation (line width larger than 25 kHz) did not yield satisfactory results, owing to the low resolution. On the other hand, the use of a spectroscope based on a molecular generator with a beam of $N^{14}D_3$ molecules [9] (line width $\sim$800 Hz) led to a resolution of the hfs of the spectrum near the principal line $J = K = 6$ [10] (K - projection of angular momentum J of the molecule on the molecular symmetry axis).

The calculation of the hfs of the inversion spectrum of ND_3 was greatly simplified in [11] through the use of the mathematical formalism of the theory of three-dimensional rotation groups, but the interpretation of the hfs of the spectrum could not be carried through to conclusion because of its high degree of complexity.

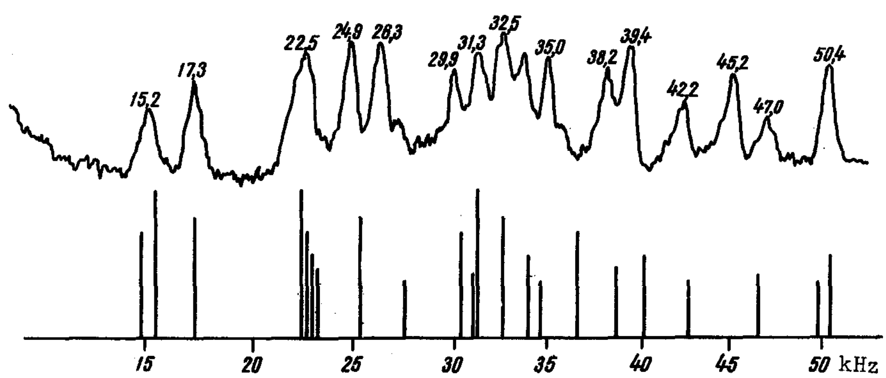
We have investigated the hfs of the inversion transitions $J = 5$, $K = 3$; $J = 3$, $K = 2$, and $J = K = 4$ using a spectroscope similar to that described in [9] (line width $\sim$ 800 Hz, accuracy of frequency measurements $\sim$ 200 Hz). The choice of the inversion line $J = 5$, $K = 3$ (frequency 1509.22 MHz) was dictated by the fact that the matrix elements of the quadrupole and spin-spin interactions, owing to their proportionality to the factor $[3K^2/J(J + 1) - 1]$ [7], decrease by more than one order of magnitude for this line, and become much smaller than the matrix elements of the magnetic dipole interaction; the form of the hfs of the spectrum thus becomes dependent essentially only on the magnetic dipole interaction constant, making the resolution of the spectrum much simpler.

The choice of the inversion line J = 3, K = 2 (frequency 1560.78 MHz) was connected with the complete vanishing, again as a result of the factor $[3K^2/J(J + 1) -1]$, of all the matrix elements of the spin-spin and electric-quadrupole interaction in first perturbation-theory approximation. Therefore the hfs of this inversion transition is determined only by the magnetic interactions of the nucleus and of the deuterium nuclei with the molecule field.

The best agreement between the calculation variants and the experimental hfs of the inversion lines J = 5, K = 3 and J = 3, K = 2 is obtained at a value $\sigma = -1.8 \pm 0.5$ kHz of the constant of the magnetic dipole interaction between the deuterium and the field of the molecule; this is more than double the value of σ given in [7, 11] ($\sigma = -4.6$ kHz).

It is most convenient to determine the electric quadrupole interaction constant from the hfs of inversion lines having K not a multiple of 3, for in this case, owing to the requirements of nuclear statistics and symmetry of the wave functions, the only possible levels are of type E with a lower symmetry than for the inversion lines with K that are multiples of 3, when the hfs levels should be characterizes by indices of the irreducible representations A_1 and A_2 of the group of permutations of three identical deuterium nuclei. From these considerations, taking into account the maximum transition intensity and the availability of the necessary apparatus, we chose for the investigations the inversion line J = K = 4 (frequency 1613 MHz), for which a comparison of the experimental and theoretically obtained variants of the hfs enabled us to find the value of the constant of the electric quandrupole interaction of the deuteron nuclei with the field of the molecule, $eq_jQ_D = -78 \pm 4$ kHz, which is significantly larger than proposed in [11] ($eq_jQ_D = - 50$ kHz), and much larger than in [8] ($eq_jQ_D = 200$ kHz).

As seen from the figure, it was impossible to obtain absolute agreement of the



Observed and theoretical (variant $eq_jQ_D = - 78$ kHz, $\sigma = -1.8$ kHz) hyperfine structure of the inversion line J = K = 4 of the $N^{14}D_3$ molecule (the figures show the principal line - satellite distances in kHz) calculated and experimental variant. We are continuing work on allowance for the interactions (in particular, in the second perturbation-theory approximation), for a more accurate determination of the obtained constants.

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HIGH-POWER SINGLE-MODE RUBY LASER

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The development of ruby laser generating one longitudinal and one transverse mode was already reported earlier [2], the maximum attained power being 2.7 MW. To obtain a higher power, we used a multi-element laser, consisting of several active rods with plane-parallel end surfaces. The rods are aligned in tandem in a spherical resonator, and the gaps between them are filled with nonlinear filters based on vanadium phthalocyanine dissolved in nitrobenzene. Such a generator is of interest from many points of view. For example, its threshold power is lower than for a solid rod having the same active-medium length and the same mirror reflection coefficients. Segmentation of the active rod makes it possible to install in the free gaps saturable filters that eliminate the coupling between the elements [2 - 4]. This makes it possible to eliminate certain undesirable effects, such as pre-generation and amplification of the spontaneous emission [2 - 5], which appear in long rods. The presence of a large number of reflecting surfaces and saturable filters has made it possible to obtain one axial mode with the pump up to 50% above threshold. Ruby crystals 120 mm long and with 0.05% chromium concentration, the first of 7 mm diameter and the second 8 mm, were placed in individual two-ellipsoid illuminators (briefly described in [1]) with two type IFP-2000 lamps. The radius of curvature of both mirrors was 2000 mm. Their power-reflection coefficients were 99.7 and 8% and the distance between mirrors was 1200 mm. The mirrors formed a convex cavity.

The cavity was Q-switched with the aid of a saturable nonlinear filter based on a solution of vanadium phthalocyanine in nitrobenzene, with initial transmission 30% at $\lambda = 6943$ Å. The filter was placed between the "dead-end" mirror and the end of the ruby rod. A similar filter with initial "transmission coefficient 50% was located in the free gap between the two rods. Besides its already mentioned function, this filter served also to sharpen the leading front of the amplified pulse [6]. The bank of K-41-I7 capacitors had a total rating of 1000